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CROSBY LOCKWOOD AND SON.

HEATING BY HOT WATER

(SECOND EDITION),

WITH

INFORMATION & SUGGESTIONS ON THE BEST METHODS

OF

HEATING

PUBLIC, PRIVATE, AND HORTICULTURAL BUILDINGS.

Treating on the HIGH and LOW Pressure Systems,
BATH APPARATUS,
HOT WATER SUPPLY for Public Institutions,
DUPLICATE BOILERS, RADIATORS,
Laundry Drying Stoves, Swimming Baths, Turkish Baths,
CAUSES of, and hints to PREVENT FAILURE;

BY

WALTER JONES.

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96 ILLUSTRATIONS.

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1894.

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PREFACE TO SECOND EDITION.

The numerous applications, and the increased demand for this work have induced the Author to prepare a *Second* Edition, the *first* having been exhausted for several months, the ready sale and the unsolicited and complimentary testimonials, are ample proof that the *first* edition has been appreciated.

One hundred pages have been added, the tables revised, and many useful ones introduced, several articles on High and Low Pressure Heating, Radiators, Duplicate Boilers, Hot Water Supply, and other matters are new, and have not before been published in any book on this subject.

The demand for artificial heating for every conceivable purpose, is rapidly increasing, and the number of Merchants, Factors, Ironmongers, Contractors, Plumbers, and Horticultural Builders who are expected to perform the duties of Hot Water Engineers increases each year.

Architects are expected to be thoroughly conversant with all the arts and sciences of the building trade, well posted up in the various systems of lighting, heating, ventilation, sanitation, &c. With these multifarious duties their time for the study of each particular branch must necessarily be limited, to such the information contained herein is specially dedicated.

Public Bodies, Town Councillors, School Boards, Guardians, Churchwardens, and others are frequently at a loss to know what system of Artificial Heating to adopt.

The Author trusts that his readers will find this a handy and useful book of reference, and that it will be accepted as an earnest effort to help all those who may be directly or indirectly interested in the useful and important art of Artificial Heating; whatever the merits of the book may be, he trusts that its imperfections will be less apparent to his readers than they are to

The Author,
W. J.

STOURBRIDGE,
January, 1894.

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CHAPTER V.—Head or pressure of water, hydraulic memoranda, avoirdupois weight, square measure, useful formulæ relating to the circle, measure of circles and angles. increased strain, risks.

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ERRATA.

Page 25.—Foot-note, read "See Rules and Examples, pages 131, 132, and Table 16, page 133."

Page 29.—Foot-note, read "See Table 22, page 214."

Page 47.—Foot-note, 2nd line, read "*from* 50 deg. to 100 deg."
3rd line, "*usual* working temperatures &c."

Page 117.—Foot-note, read "See Area of Pipes, Table 14, page 128."

HEATING BY HOT WATER.

CHAPTER I.

THE HIGH PRESSURE SYSTEM.

THE system of heating known as the "hot-water system" is simply a ready and convenient method of conveying and distributing heat from a given point to any other point where it may be required. There are two distinct systems or methods of doing this, known as the "high pressure" and the "low pressure"; and, although there is a wide difference in the two systems, the principle and its application are similar. The heat is in both cases transmitted from the boiler or heating-chamber to the room or rooms where the heat is required.

The high-pressure system consists of a series of strong wrought-iron tubes, similar to hydraulic tubes, the boiler being coiled from the same material. The size or number of laps contained in the boiler depends on the length of pipes that require to be heated.

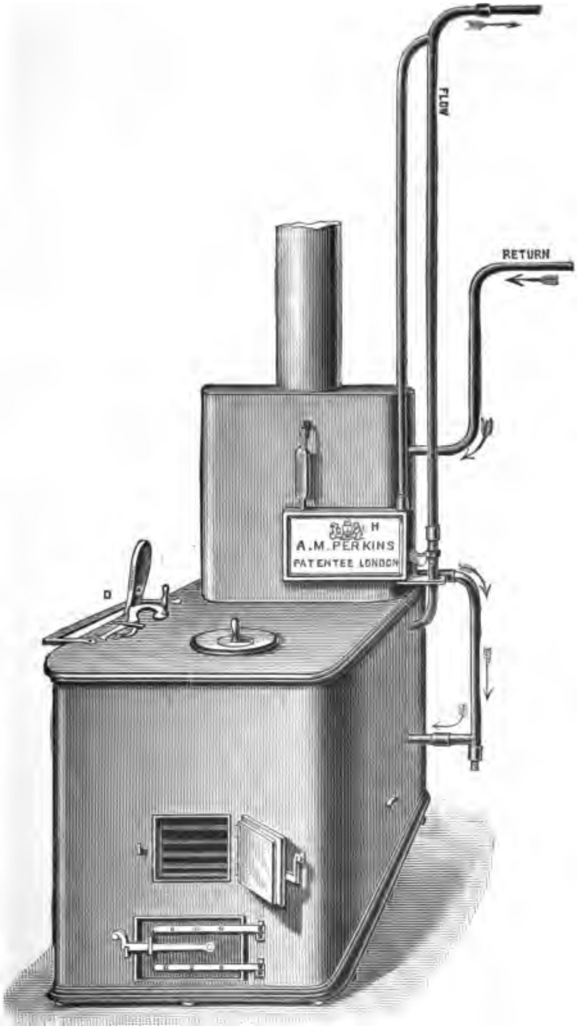
This system was introduced by Mr. A. M. Perkins, of London, and is commonly known as "*Perkin's system ;*" his first invention, which included the Expansion tube, was protected by Royal Letters Patent, No. 6,146, in the year 1831.

His son, Mr. Loftus Perkins, succeeded him, and the business is still carried on under the title of A. M. Perkins and Son, Limited, the two sons of the late Mr. Loftus Perkins being members of the present firm. As pioneer of this system, Mr. Perkins had to contend with strong prejudices, and he must have possessed not only inventive power, but constructive skill of no ordinary ability, for although 60 years have elapsed since its introduction, the patterns of boilers and other accessaries invented by him, have been closely followed by all other makers of high-pressure apparati.

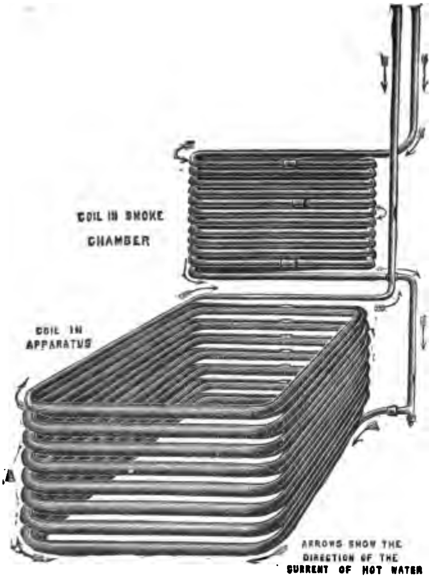
Comparatively few important improvements have been made, although there are some deserving of special mention as will appear further on; certainly the development has been trifling compared with the important strides made in low-pressure heating.

In confirmation of this statement it is only necessary to compare the appliances still in general use, with the illustrations, Fig. 1, 2, 3, and 4, which are reproduced from a book (kindly lent to me for this purpose) published in 1840, entitled "*A. M. Perkin's Improved Patent Apparatus for Warming and Ventilating Buildings.*"

The illustrations Fig. 5 and 6 are copied from a book (now in my possession) printed in 1837, entitled "*Warming and Ventilation by C. J. Richardson, Architect,*" wherein he shows some of the details of construction. I would point out that the arrangement of valves in Fig 5 is bad, a bye pass being necessary to allow of circulation when valves are closed, otherwise an explosion may happen, and, although Mr. Richardson's book shews this arrangement, it is improbable that a point of such importance would have been overlooked by the inventor.

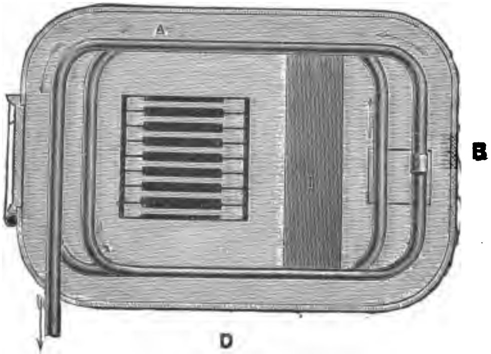


VIEW OF BOILER.
Fig. 1.



VIEW OF PIPES

C



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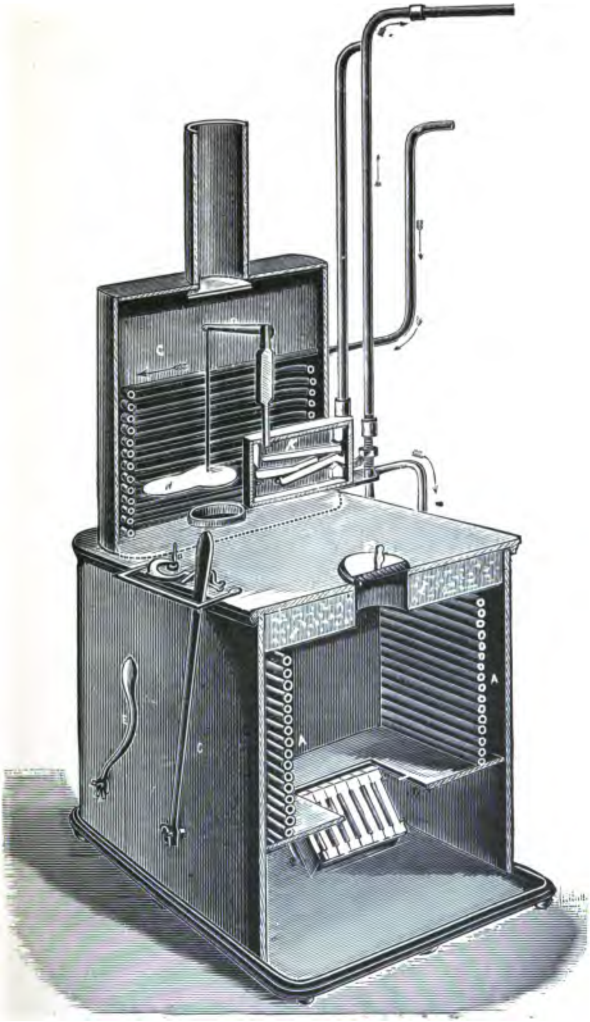
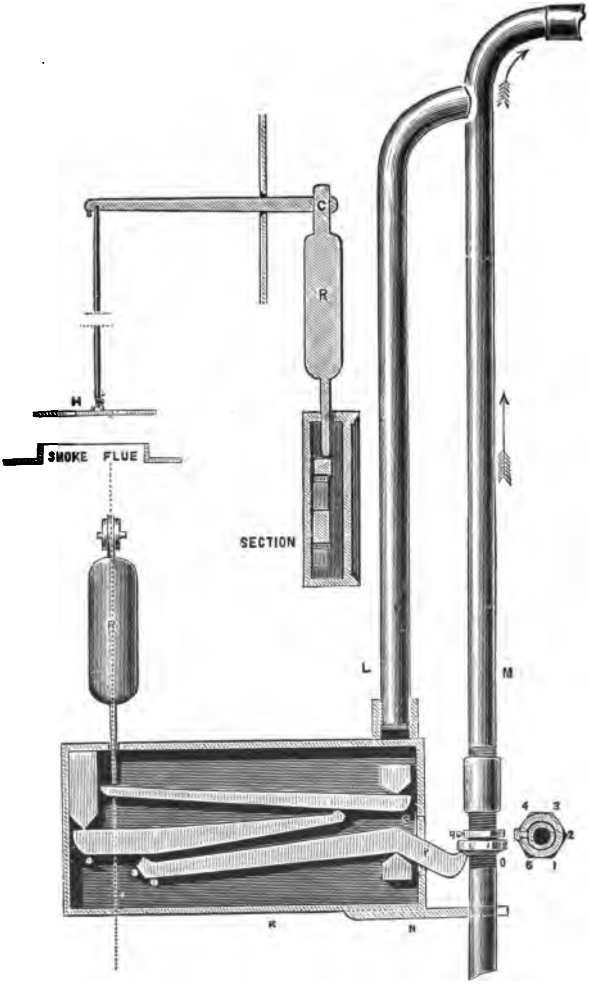
PLAN ABOVE CRATE.

Fig. 2.



SECTION ON LINE C.D.

Fig. 3.



GOVERNOR OR HEAT REGULATOR.

Fig. 4.

The book referred to contains illustrations of several buildings heated by Mr. Perkins, a reference to Fig. 1, 2, 3, 4, 5, and 6, will shew that the boilers, and other accessories are almost slavishly copied by most makers at this date. There are, however, boilers of different design, some with larger tubes, thus presenting a greater surface to the flame; but alterations are not necessarily improvements, and the test of merit is, what will give the best results with the least risk, and the smallest consumption of fuel? Until I have had further opportunities of practically testing the merits of the various boilers, I will suspend my own judgment, and leave others to form their own opinion. I may, however, state that boilers are made of ⅞-in. bore tube, capable of heating 10,000 feet of tubing, and I think this is quite as much as ought to be put on one boiler.

One advantage that may reasonably be urged in favour of powerful boilers being made from larger tubes is, that the increased area, and the smaller number of bends required, would reduce the friction, which is excessive in every form of high-pressure apparatus, as proved by the great difference in temperature between the flow and return pipes.

The tubes originally used were ⅝ inch bore, but experience has proved that a pipe of ⅞ bore is more suitable and convenient, and this size is now almost universally adopted for all classes of high-pressure work, irrespective of the size of the apparatus; other sizes of pipes are occasionally used, some makers preferring 1-in, others 1¼-in, or still larger sizes for portions of the apparatus, it is, nevertheless, a very great convenience to adopt some universal standard, and the alteration and multiplication of sizes should not be entertained unless some special advantage is derived therefrom.

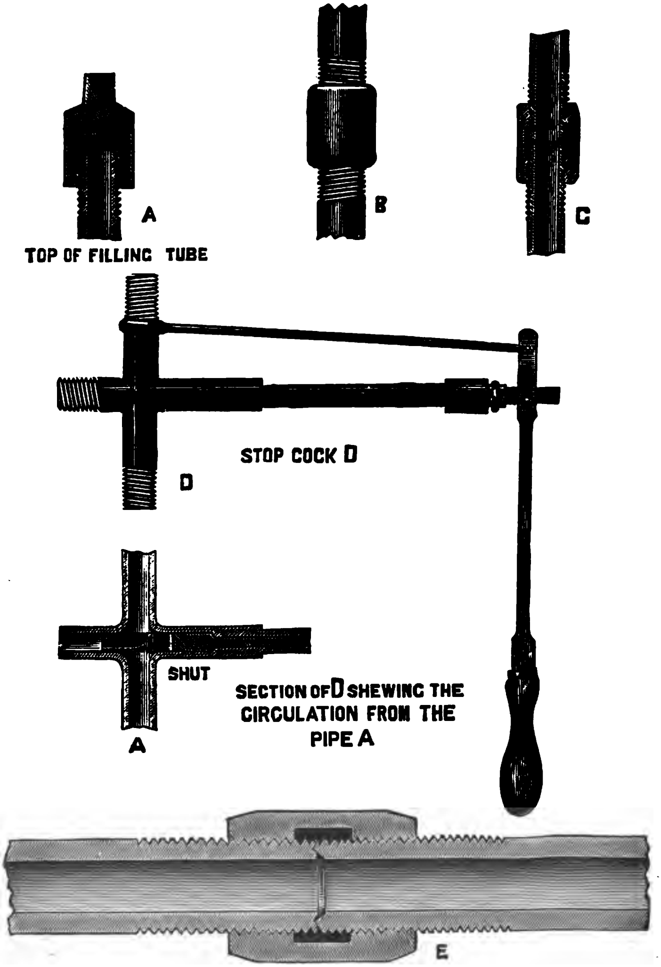

A
TOP OF FILLING TUBE
B
C
STOP COCK D
D
SHUT
SECTION OF D SHEWING THE CIRCULATION FROM THE PIPE A
A
E

Fig. 5.

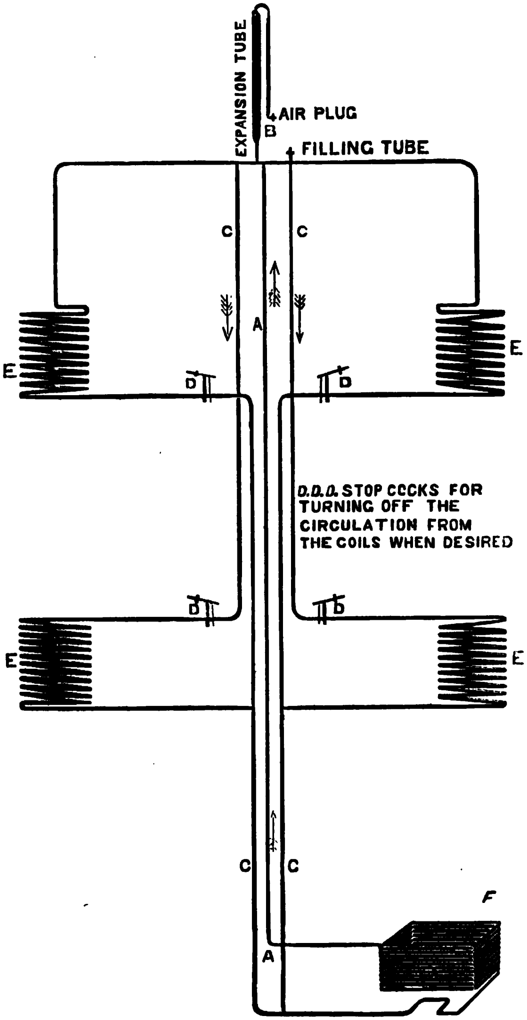

EXPANSION TUBE
AIR PLUG
B
FILLING TUBE
C
C
A
E
E
D
D
D.D.D. STOP COCKS FOR TURNING OFF THE CIRCULATION FROM THE COILS WHEN DESIRED
D
D
E
E
C
C
A
F

Fig. 6.

At the highest point of the apparatus is fixed a larger tube, called the "air-vessel" or "expansion pipe." The pipes are filled from the lower level **P** near the boiler (see Fig. 7) by means of a force-pump until the water reaches an overflow pipe, which is fixed above the level of the circulating-pipes, and at the base of the air-vessel or expansion-pipe. The overflow is then sealed by means of a screwed cap or plug, and the apparatus tested to a pressure of from 1,000 to 3,000 lbs. on the square inch. This may appear unnecessary, and to some incredible; but as the pipes are hermetically sealed after they are filled, the necessity will be obvious.

The Syphon bend **S** is to prevent the water backing up the return pipe, which it is apt to do, especially when the intense heat of the fire is acting on the lower part of the boiler.

In the process of heating, water expands about one twenty-third of its bulk, so that 23 gallons of cold water would, when heated to 212°, be equal to 24 gallons, and the air in the air-vessel (being more elastic than water) is compressed by this expansive force, hence if provision were not thus made it would inevitably burst the pipes ; they are subject to a working-pressure varying from 50 to 500 lbs. on the square inch, and where high temperatures have to be maintained, as in stoves or ovens, it sometimes exceeds even the great pressure above mentioned.

The whole of the apparatus contains only a few gallons of water, hence the circulation is very rapid, and an intense heat is thrown off from the pipes. To stand the enormous strain to which they are subjected, the ends of the pipes are carefully prepared by machinery ; one end is flattened or faced, and the other is tapered inside and out to a sharp conical edge (see Fig. 8) ; the pipes are cut with right and left-hand threads, and the screwing up of the

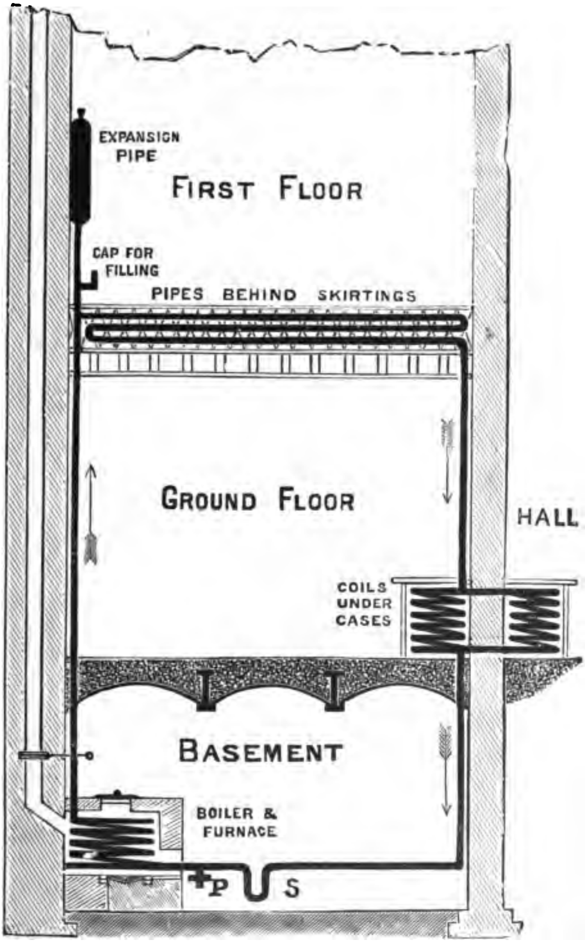


Fig. 7.

Fig. 7.—Complete High-pressure Apparatus. P, Pumping Cock for filling; S, syphon bend.

sockets with powerful pipe-tongs draws the two pipes together simultaneously ; the joint does not require white lead or yarn, as it is formed by metallic contact, the coned edge of one pipe being forced into the flat end of the other, which makes a joint as strong as the solid pipe itself.

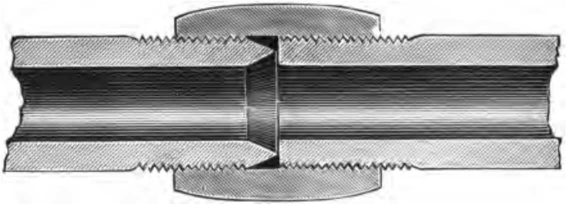


Fig. 8.

It is sometimes urged in favour of this system that it is more economical, and that owing to the small quantity of water to be heated the consumption of fuel is necessarily smaller than that used by the low pressure system. Several reasons may be given to show that such is not the case, and the following will tend to disprove this theory.

1. The consumption of fuel depends on the area of the fire-bars and the rapidity of draught, and not on the size of the pipes, or the quantity of water they may contain.

2. To ensure economy of fuel it is necessary to have a large heating surface exposed to the flame impact, and so arranged that the heat shall be spent on the boiler, and not on the brick-work in which it is cased.

3. The colder the boiler-surface when exposed to the flame, the greater the heat it will receive ; and as the coil boiler is nearly three times hotter than the low pressure, there must be a proportionate waste of fuel.

In proof of this statement I give one or two (out of many) tests I have made. The results may be verified by others desirous of proving it for themselves.

Test 1.—Ten gallons of water in a tank heated (by circulation) from copper boiler with atmospheric-gas burner:—

Time.	Temperature of Water.	Temperature raised.
h. m.	Fahr.	Fahr.
7 0	60 deg.	— —
7 15	92 „	32 deg. in 1st quarter hour.
7 30	116 „	24 „ 2nd „
7 45	138 „	22 „ 3rd „
8 0	158 „	20 „ 4th „

The consumption of gas (being carefully registered), was the same for each quarter hour.

Test 2.—Twenty-five gallons of water circulated through 50 feet of 4-inch pipes, from copper boiler with atmospheric-gas burner:—

Time.	Temperature of Water.	Temperature raised.
h. m.	Fahr.	Fahr.
10 30	50 deg.	— —
11 0	68 „	18 deg. in 1st half-hour.
11 30	80 „	12 „ 2nd „
12 0	90 „	10 „ 3rd „
12 30	98 „	8 „ 4th „
1 0	104 „	6 „ 5th „
1 30	110 „	6 „ 6th „
2 0	114 „	4 „ 7th „

The difference in the number of degrees for each consecutive half-hour varies more here than in the No. 1 test, but this is easily explained, for, while the boiler absorbs less heat, the pipes (having a greater cooling-surface than the tank) part with the heat more rapidly as the temperature of the water is raised.

The above Tests show conclusively that the nearer the temperature of the boiler approaches that of the gas flame, the less rapid is the absorption of heat; * and when either fire or steam are employed as the heating agent, the results are much the same, the colder the water, the more rapidly will the heat be absorbed.

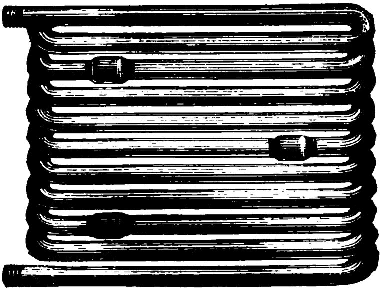


Fig 9.

Figure 9 illustrates a coil of bent tube for concentrating a large radiating surface in a confined space, which may be covered with an ornamental coil case when desirable.

The intense heat thrown off by these pipes sometimes causes a disagreeable and unwholesome smell, arising from the decomposition of small particles of animal and vegetable matter that are constantly floating in the air, and thus come in contact with the pipes, or from a chemical change caused in the air when passed over metals which are intensely heated; for this reason it is not suitable for small or insufficiently ventilated rooms.

When a high-pressure apparatus is well and properly fixed with a good head of water, the circulation is free and rapid; but the small diameter of the pipes causes increased friction, which necessitates great care in fixing. A low head of water or a dip in the pipes will often start the water to work back up the return pipe, and cause a concussion and thumping noise, which is not only disagreeable, but increases the pressure, and throws an unnecessary strain on the apparatus; the lower portion of the boiler may be thus emptied of water, and with a strong fire the coil will be weakened by the intense heat. This portion of the apparatus is usually the first to show signs of weakness.

---

* See test No. 5, page 28.

It has been frequently stated that high pressure apparata are exceedingly dangerous; it should be here stated in all fairness that this is not necessarily the case. They may be erected by skilful and competent persons, so that the maximum pressure would not exceed 50 lbs. on the square inch; and, considering the strength of the materials used, this may be considered perfectly safe. The source of danger is more commonly from incompetent work rather than from the fault of the system. It must not be supposed that an apparatus with dips will not work, they are frequently fixed with a large number of coils, carried up and down in a most fantastic manner, and when thus fixed, the water must be forced through (with pump) so as to completely dislodge all the air before the apparatus is started. It is, nevertheless, desirable to avoid these dips as far as possible.

Any exposed portion of the apparatus, owing to the small bore, is speedily affected by frost, and in all cases where water only is used, the apparatus should either be emptied, or the fire kept constantly going in severe weather, as a few hours' frost may split the pipes, or cause an obstruction of ice sufficient to prevent circulation, and thus become a source of danger if the fire were started. This difficulty may be obviated by filling the apparatus with an anti-freezing liquid (supplied at a slight extra cost) instead of with water.

Figure 10 shows the method of fixing pipes against a raised floor, as the aisle of a church, &c.

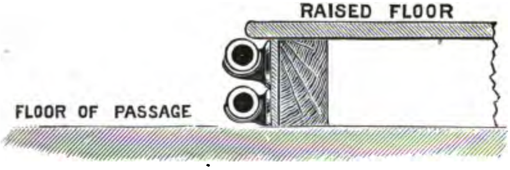


Fig. 10.

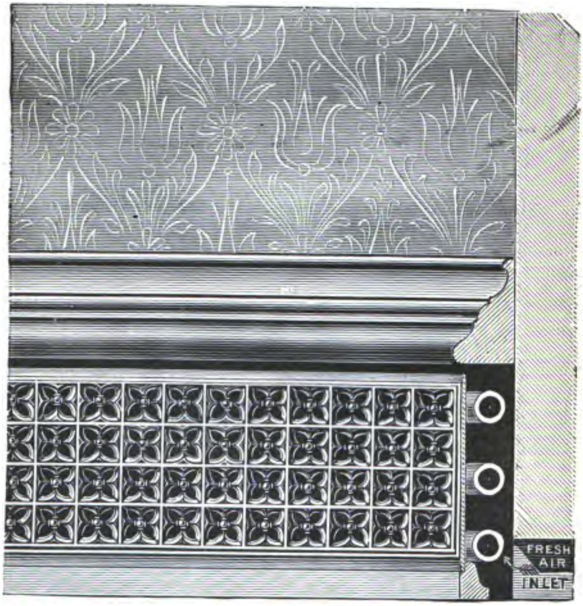


Fig. 11.

11.—Pipes behind Skirting of Room, and covered with Ornamental Gratings.

The form of boiler generally used for quantities of pipes up to 1,500 ft., is similar to Fig. 2, page 10, but without the upper coil in smoke chamber, the furnace coil being surrounded by a wrought iron casing, thus forming a self-contained boiler; for larger quantities (from 2,000 up to 10,000 ft. of pipes) the boilers are frequently set in brickwork. Several makers have special shapes or designs, and some of them adopt tubes of larger diameter.

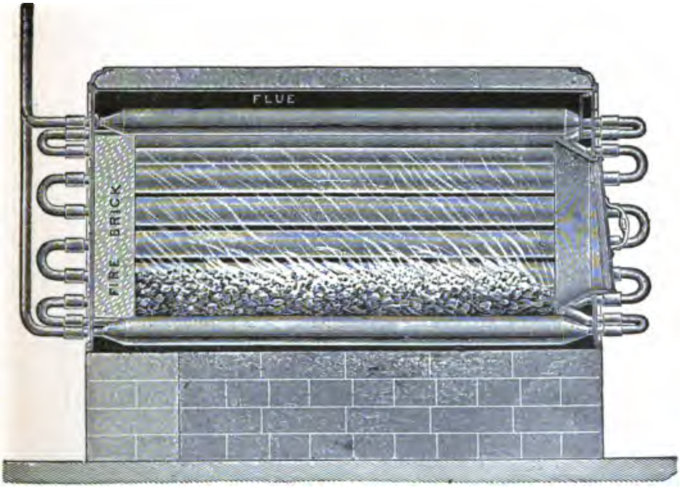


Fig. 12.

Fig. 12 is a section of this class of boilers. Patented Jan. 6th, 1877, No. 68, by Robert Renton Gibbs, of Liverpool.

The tubes are arranged in the form of a circle which forms the fire box or furnace, the ends of each tube being reduced to $\frac{7}{8}$ inch and connected with syphon bends, and arranged with one or more circulations, according to the quantity of pipes to be heated.

For the erection of heating-apparatus on the high-pressure system, proper appliances, good judgment, and a certain amount of skilled labour are absolutely necessary; and although the system is largely adopted, and, when properly fixed, is very convenient and useful, in the hands of an unskilled workman it may be fraught with danger.

It is not intended to give all the minute details of construction, but the following are some of its leading features:—

The tubes are $\frac{7}{8}$ inch inside diameter by $1\frac{5}{16}$ inches outside diameter.

The end of the tube which has a right-hand thread, is flat or faced; the end with a left-hand thread is coned.

The sockets are about $2\frac{1}{4}$ inches long by $1\frac{15}{16}$ inches outside diameter, and have a right-hand thread in one end, and a left-hand thread in the other; the centre of the socket inside is cut away below the bottom of the thread, thus dividing the right from the left-hand thread (see Fig. 8, page 18).

The tees and crosses are similar to the tubes, $\frac{7}{8}$ inch bore throughout, and are connected with sockets at each end.

The pitch of thread is fifteen threads per inch (being a finer pitch than that of ordinary gas or steam tubes). This does not weaken the tube so much, and it gives a powerful leverage by which the joints may be screwed more firmly together.

The water contained in 100 feet run is about 2·5 gallons, *i.e.* 1 gallon to every 40 feet run.

Coil boilers are frequently fixed at the back of, or in connection with, ordinary firegrates, and the radiating pipes conveyed to rooms on the floor above, a very convenient means of warming two or more rooms from an fire.

I am not aware of any work yet published that gives the length of pipes, and the proportionate boiler power required to obtain various temperatures by high pressure heating. The table given below is based upon results I have already obtained, and has been confirmed by Mr. Stainton of London, who has had an extensive experience in high pressure work. As the flow pipe is more effective than the return, the proportions should be varied accordingly, especially when a number of rooms are heated from one boiler, as 10 feet of the flow may be more efficient than 20 feet of the return pipe.

TABLE No. 1.

Length of **High Pressure** pipe ($\frac{7}{8}$ in. bore) required **for every 1,000 Cubic feet,** and proportionate length of tube in boiler, with an outside temperature of 30° Far.

To give an inside temperature of		Length of $\frac{7}{8}$ tube required per 1,000 cubic feet.	Proportionate length of tube in boiler
Ordinary rooms, offices, or public buildings.	55 deg. Far.	14 feet.	$\frac{1}{10}$th the length.
	60 ,,	16 ,,	,, of radiating pipes
	65 ,,	18 ,,	$\frac{1}{9}$th ,,
	70 ,,	22 ,,	,, ,,
	80 ,,	32 ,,	$\frac{1}{8}$th ,,
Drying stoves or closed rooms.	100 ,,	60 ,,	$\frac{1}{8}$th ,,
	150 ,,	120 ,,	,, ,,
	200 ,,	200 ,,	$\frac{1}{7}$th ,,
	250 ,,	400 ,,	$\frac{1}{6}$th ,,
	300 ,,	600 ,,	$\frac{1}{5}$th ,,

Note—if the boiler is made of larger tubes, take the *Superficial* surface* of radiating pipes, and allow a proportionate amount *super* of heating surface in boiler.

* See table 12 at end of book.

Expansion Tubes vary from 2 in. to 6 in. diameter, the length and proportion should be carefully considered. The *capacity* should be proportionate to the *quantity* of water contained in the whole of the apparatus, and the *strength* to the *temperature* at which it is to be worked. The volume, or bulk of water (any quantity) taking 40^0 Far. (the maximum density) as the unit = 1.

The volume of the same *weight* of water at 212^0 = 1·043 being increased in bulk $4\frac{3}{10}$ per cent. (nearly $\frac{1}{23}$), whilst at 600^0 the increase is 31 $^0/_0$ (nearly $\frac{1}{3}$rd).

From this it will readily be seen that it is possible to burst any apparatus, if due allowance is not made for this expansion, and if no allowance were made this may occur even before the water boils.

The following table shows the increase in bulk of water at different temperatures, and the capacity required for the "expansion" above the water level of filling pipe, it must be borne in mind that with the higher temperatures, the pressure increases enormously, and it is essential that all parts should be proportionately strong to withstand this pressure.

TABLE 2.

Increase in bulk of **water** and proportionate **size** of **Expansion** pipe.

Temperature of water in flow pipe near boiler.	Expansion.	Increased bulk per 100 gals.	Allow in expansion pipe an air space equal to	
40 deg. Far.	1·	100 galls		
100 ,,	1·0075	100·75		
200 ,,	1·038	103·8		
212 ,,	1·043	104·3	$\frac{1}{23}$	the quantity of water contained in the whole apparatus.
300 ,,	1·086	108·6	$\frac{1}{10}$	
400 ,,	1·148	114·8	$\frac{1}{6}$	
500 ,,	1·223	122·3	$\frac{1}{4}$	
600 ,,	1·310	131·0	$\frac{1}{3}$	

The following tests, made with a column of mercury in contact with the flow-pipe of a small apparatus, the glass bulb of a Farenheit thermometer being immersed in the mercury, give the temperatures, and the corresponding pressures registered with a "Schaeffer & Budenberg" pressure-gauge:—

TEST NO. 3.—*When* 1,300 *lbs. Pressure on the Square Inch Registered a Temperature of* 500 *degrees Farenheit.*

Temperature.	Pressure on the Square Inch.	Temperature.	Pressure on the Square Inch.
Fahr.	Lbs.	Fahr.	Lbs.
200 deg.	25	400 deg.	525
230 ,,	75	400 ,,	950
270 ,,	125	400 ,,	1,000
300 ,,	275	430 ,,	725
330 ,,	450	430 ,,	1.000
340 ,,	575	450 ,,	1,050
350 ,,	450	460 ,,	1,100
370 ,,	325	470 ,,	1,200
380 ,,	725	500 ,,	1.300

Time occupied in test, about one hour.

TEST NO. 4.—*With a more Sensitive Gauge Shows the Fluctuations in Pressure up to* 100 *lbs.*

Temperature.	Pressure on the Square Inch.	Temperature.	Pressure on the Square Inch.
Fahr.	Lbs.	Fahr.	Lbs.
50 deg.	0	170 deg.	13
55 ,,	2	180 ,,	14
55 ,,	6	190 ,,	8
55 ,,	9	200 ,,	15
60 ,,	10	210 ,,	25
70 ,,	12	220 ,,	32
90 ,,	16	230 ,,	50
100 ,,	16	240 ,,	32
110 ,,	18	245 ,,	60
120 ,,	20	250 ,,	89
130 ,,	11	260 ,,	72
140 ,,	11	270 ,,	80
150 ,,	4	270 ,,	100
170 ,,	10		

Time occupied in Test about 30 minutes.

It will be observed that the pressures fluctuate, commencing before the water boils, and do not follow on gradually with the increased temperatures. I have noticed the same peculiarity in other tests, the pressure suddenly decreasing while the temperature has been rapidly rising; this is caused either by partial generation of steam or by undue friction in the pipes, caused by the displacement of air, and strengthens the argument that great care should be exercised in the erection of high-pressure apparatus, and that the work should not be entrusted to inexperienced persons.

The following is a test (taken March 3rd, 1882), of an apparatus erected at the Smoke abatement Exhibition, South Kensington, by Mr. Stainton, King's Cross, London, showing the temperatures in flow and return pipes, and the working pressure to the square inch. TEST No. 5.—

Temperature of water in flow pipe.	Temperature of water in return pipe	Temperature raised each half-hour.	Pressure in lbs. per square inch.
50 deg.	44 deg.	Far.	0
180 ,,	54 ,,	130 deg.	0
300 ,,	160 ,,	120 ,,	1,100
360 ,,	234 ,,	60 ,,	1,000
404 ,,	266 ,,	44 ,,	500
400 ,,	318 ,,	4 ,, lower	400
415 ,,	326 ,,	15 ,,	400
425 ,,	334 ,,	10 ,,	560
432 ,,	340 ,,	7 ,,	560
442 ,,	342 ,,	10 ,,	560
383 ,,	325 ,,	59 ,, lower	250

Time occupied in test, 5 hours.

Temperature registered every 30 minutes.

The difference between the temperatures of the flow and return pipes varies from 58° to 140°, and throughout the test shows an average difference of 104°.

Note also, that with 300° temperature the pressure is 1,100 lbs., and when the temperature is increased to 442° e pressure is reduced to 560 lbs. on the square inch.

The relative proportion of pressure to temperature here given varies considerably from the table of "The Expansive Force* of Steam," by MM. Dulong and Arago, quoted by Hood in his "Hot-water Heating;" and as I may have occasion to note other discrepancies, I may here state that it is with no intention to disparage that useful work, which has doubtless been the means of developing an important industry, that this remark is made. The author of that work is unquestionably entitled to the highest praise and the warmest thanks of his fellow-countrymen.

ADVANTAGES OF THE HIGH-PRESSURE SYSTEM.

The system is specially applicable where high temperatures (say 100° to 300°) are required, such as japanning-stoves, drying-closets, laundry purposes, &c.

It is suitable for warehouses, large rooms, entrance-halls, or places that are well ventilated.

It is frequently used for churches, schools, public buildings, offices, &c.

It may be used with advantage to assist ventilation, either inlet or exit.

The pipes being of small diameter are neater in appearance, and may be fixed behind skirting-boards and in confined places where large pipes would be unavailable.

They can be readily bent to suit any angle.

The pipes being hermetically sealed, the waste of water is very slight.

The temperature of the water is raised in a short time, owing to the large heating-surface and the small quantity of water to be heated, which causes a rapid circulation.

---

*See Table 14 at end of book.

CHAPTER II.

Another adaption of **high pressure** heating (sometimes called the medium pressure), is to substitute a supply cistern containing a relief valve in place of the expansion tube. *See letter A*, *Fig.* 13.

This system was also invented by Mr. A. M. Perkins in 1839, and protected by a patent, No. 8311. It does not appear to have been extensively used at that date, and although some other firms have since made a speciality of this particular system, there is no doubt that Mr. A. M. Perkins was the original inventor.

Where excessive temperatures are required say from 150° to 350° the expansion tube is undoubtedly the best, but where ordinary temperatures are required, say under 100°, the cistern with relief valve is considered by some makers to be more suitable. The following advantages being claimed for it :—

1. The water is *not* hermetically sealed.

2. The pressure is a known quantity that cannot be exceeded.

3. Prevents excessive pressure by releasing the air, and any undue pressure of water, which is taken back automatically from the cistern into the pipes as they cool down again.

4. Stop cocks (for regulating or shutting off portions of the heat) may be more freely used, and are less liable to derangement.

5. Milder heat, pipes being worked at a lower temperature.

6. Water may be added in cistern at any time without withdrawing the fire and waiting until the apparatus is cooled down.

I stated that comparatively few important improvements had been made, and that there were some deserving of special mention, such as improvements in stop cocks, pumping cocks, relief valves, and last but by no means the the least is the " Anti Frost " or frost defying liquid.

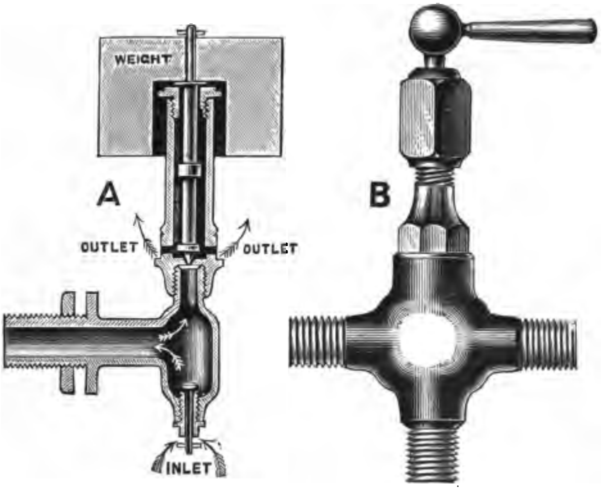


Fig. 13

Letter A, Fig 13, illustrates (in Section) a very good form of dead-weight relief valve, registered (No. 188795) by Mr. W. Stainton, of King's Cross, London. In case of excessive pressure the water escapes through the outlet as indicated by the arrows, into the supply cistern ; as the water cools a vacuum is formed, and the water returns through the inlet valve.

The stop cock Letter B, Fig. 13, is also registered by Mr. Stainton, and gives a full bore opening throughout. The stop cock for high pressure work may perhaps be more correctly described as a diverting valve, for changing or diverting (by means of a bye-pass or short circuit) the course of the water when the heat is not required in any given portion. This is accomplished by means of a three-way valve, so constructed that the inlet or flow may be introduced through a hollow plug or spindle in the lower or vertical portion, and circulated either to the right or left, or simultaneously through both branches, as may be required. It will be evident that the introduction of a valve of any description that would absolutely cut off or prevent circulation would be fraught with danger.

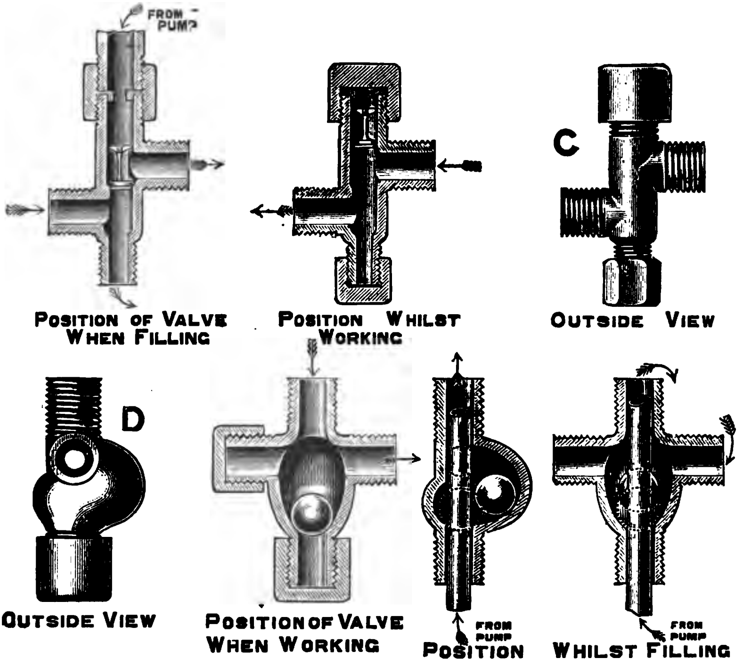


Fig. 14.

The pumping valve Fig. 14, letter C, was invented and patented by Mr. Stainton, Nov. 20th, 1880. The design is also registered, No. 188796.

Letter D shews view and three sections of a pumping valve patented No. 68, Jan. 6th, 1877, by Robert R. Gibbs, the illustrations will shew the action of each without further description.

I believe the credit for producing an anti freezing liquid that was not injurious to the apparatus was also due to Mr. W. Stainton. It was protected by Royal Letters Patent, and the first apparatus filled with it in 1876, is still working satisfactorily, having been occasionally re-pumped since that date. In times of severe frost, terrible havoc is frequently made with small bore boilers and pipes when charged with water only, and the small extra cost for filling with anti freezing liquid is a good investment, especially where the pipes are used for ventilation, either inlet or exit, as, when thus exposed to the air currents, they are quickly affected by frost.

There are four methods of fixing high pressure apparatus, which may be described as Single, Duplicate, Branch, and Crossed circulations.

Single circulation is when a single coil boiler is used, and the radiating pipes continued in a single circuit, *i e.*, one flow, and one return. This method is generally adopted for a small apparatus, say up to 500 ft. of pipes, one pumping cock and one expansion tube only being necessary.

Duplicate circulation has two or more furnace coils, each having a separate circuit of radiating pipes connected to same; a pumping cock and expansion tube being required for each circuit, the arrangement is not often adopted, although under certain circumstances it has its advantages.

Branch circulation. Branches are sometimes taken off the main flow and return pipes, by means of T or Y pieces, thus giving two or more circuits from a single furnace coil, the object of this is to shorten the circuit, reduce the friction, and get the water returned to the furnace quicker: great care and good judgment are required when this mode is adopted, as it is difficult to displace the air, the accumulation of which in either circuit will prevent the proper working. Another difficulty after the air is displaced is that if one circuit is shorter than another, the hot water will take the short circuit first, and prevent the longer one from working. Branch circulations are specially suitable where stop cocks are used for shutting off portions of the system. Air cocks are very rarely used with high pressure work, they may occasionally be introduced with advantage where this mode of fixing is adopted, they should, however, be specially constructed, and much stronger than the air cocks commonly used with low pressure apparati.

Crossed Circulations.—This method is most frequently adopted, and is generally the most convenient for long ranges of pipes, for instance, when 1,000 feet of pipes are required, two circuits of 500 feet each are better than one of 1,000 feet, in the latter case, the return pipe would be practically cold before reaching the boiler, and the heating surface would be of little or no value. These circulations (sometimes 8 or 10 in number) are connected in such a manner, as to form one endless tube of boiler and pipes.

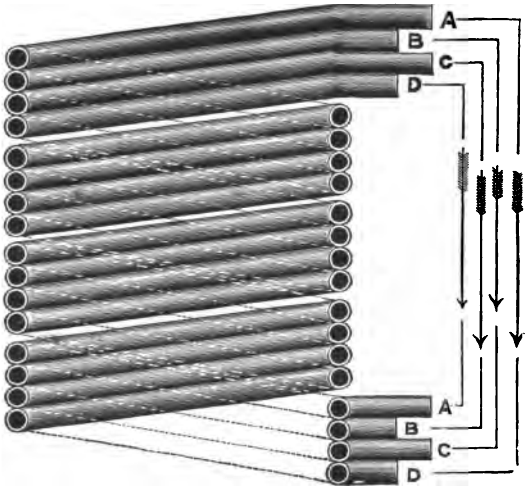


Fig. 15.

Fig. 15 shows a boiler of this description with four circulations A B C and D, the water from A returns to D, from B to C, from C to B, and from D to A, the pumping cock or valve being in the lowest return pipe, and one or more expansion tubes on the highest parts of the system.

Now if a stop-cock were fixed on any portion of such a circuit, it will be obvious that no circulation could take place, and to get over this difficulty, when it is required to cut off any section, a short branch circulation must be substituted so that the circuit may be continued.

High-pressure Pipes are frequently carried up and down irrespective of levels, through a series of coils in a manner so erratic, that if attempted with a low-pressure apparatus, would force the water out of the cistern, and defy all attempts to make it circulate, and from this it is often inferred that the circulation is caused by increased pressure, and that it can be forced anywhere irrespective of gravitation ; such is not the case however. Dips and other obstructions are more readily overcome in a high-pressure apparatus for two reasons. First, owing to the small quantity of water and consequently, the greater difference of temperature between the flow and return pipes, and as the water cannot be forced out of the apparatus the temperature in flow pipe can be raised much beyond the boiling point, and Second, the head of water can often be increased with small pipes where it would be either impossible, or impracticable with low-pressure pipes, and the increased head of water is the best way where practicable, the circulation will be more rapid, the return pipe hotter, and hence the heating power will be more effective, it is better in all cases to avoid dips if at all possible to do so. It may surprise some to hear that a high-pressure apparatus now in daily use is so fixed, that by the adjustment of the damper and the regulation of the fire, it will work either backwards or forwards, occasionally reversing its action, without noise or strain in the apparatus, and circulate down the boiler and up the return pipe freely for hours together without the slightest inconvenience.

CAUSES OF FAILURE.

Some of the most common are :—

Faulty construction.
Insufficient boiler power.
Insufficient radiating surface.
Various parts of apparatus not proportionate.
Fixed by inexperienced persons.
Not properly pumped or filled, hence air locked.
Pipes blocked with ice during frost.
Accumulation of soot and dust in boiler flues.

USEFUL HINTS.

First.—To anyone requiring this class of work done, entrust it to those who have had some experience, and who have a reputation to maintain, or in whom you can place implicit confidence.

Second.—To those about to commence as high-pressure fitters, and who have not had the necessary experience, perhaps the best advice would be that given by *Punch* "To those about to marry, Don't" unless you are prepared to buy your experience, or to lose some cash. A complete set of good tools is an essential requisite.

Every apparatus should be well pumped to dislodge all air, then tested with a powerful force pump to from 1,000 lbs. to 3,000 lbs. pressure; if excessive temperatures are required, or if the apparatus has a number of dips, it should also be tested with pressure gauge whilst working, and if the gauge shows excessive pressure, the apparatus should be carefully overhauled and corrected before leaving it.

For temperatures under 100°, stop cocks may be used and the cistern and relief valve system, but for high temperatures, stoves, &c., the expansion pipe is best, and stop cocks should be avoided.

Soft water should be used for filling apparatus, especially where the hard water has an excessive amount of lime or other deposits.

Instructions for working should be supplied with each apparatus and hung in boiler house, the following is a copy of the instructions used by the writer for a sealed up apparatus with expansion pipe. If with cistern and valve, omit the two first lines.

INSTRUCTIONS FOR WORKING.

1. Before starting the fire, unscrew air plug on expansion tube, remove cap from filling pipe, and see that pipes are quite full, and securely screw up cap and plug.

2. This should be done weekly, or at most fortnightly when apparatus is quite cold.

3. Cover the firebars with small coke, or smokeless coal, then start the fire. Slack should not be used.

4. Fire door, feeding door, and soot doors should not be left open.

5. Regulate draught with damper and ashes door.

6. If fire gets dull, rock (with lever) the firebars.

7. Clinkers may be removed by tilting the firebars.

8. If any kicking or thumping noise in pipes, check the draught with damper.

9. If noise continues, apparatus requires water.

10. Banking up for the night; fill with small fuel, push in damper as close as will permit without smoke or sulphur escaping.

11. Flues should be thoroughly cleansed from soot or dust through the soot openings in front, and also (by means of lever) through trap door at back of furnace, once or twice a week.

12. During frost, keep apparatus working, or have it filled with anti-freezing liquid.

13. Churches or Chapels should be warmed on Saturday, fire banked at night, pipes well heated before service, the fire reduced, and pipes cooling during service.

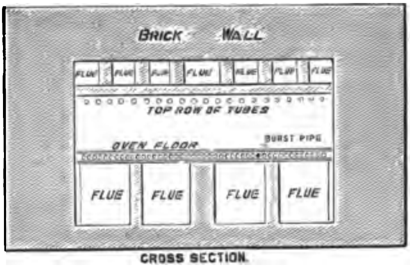
14. Leakages, however slight, should receive immediate attention.

CHAPTER III.

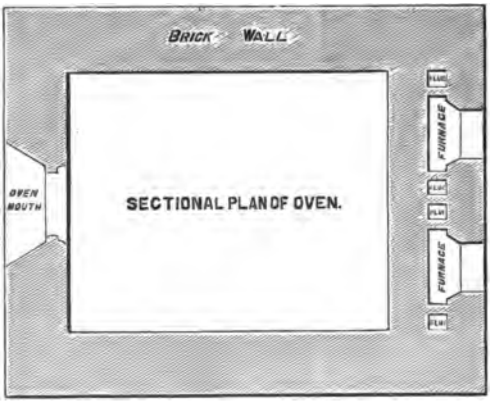
BREAD BAKING BY HOT WATER (OR STEAM).

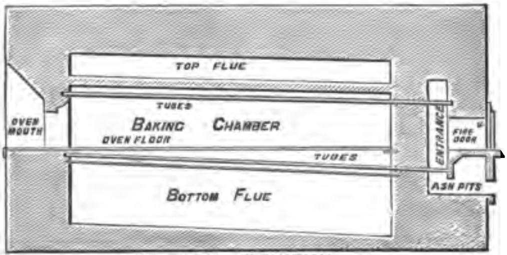
To the uninitiated, the idea of heating ovens for baking bread, biscuits, &c., with hot water tubes would be considered only as a joke, or a theoretical fancy, there is, however, nothing chimerical about it, for the system has been fully tested and is used extensively for this purpose; the arrangement is quite different from the ordinary methods already described; no expansion tubes, relief valves, pumping cocks, or other connections are required; instead of a continuous-circuit of pipes, for circulating water, a series of tubes are fixed above and below the baking level, or floor of the oven, the number and length of the tubes varying according to the size of the oven. One end of each tube is first welded up, a certain proportion of water (usually about one-fourth or one-fifth the capacity of the tube) is put in, and the second end of the tube is then welded up, thus hermetically sealing the water in each tube; the bottom row of tubes form the fire bars, and extend the full length, and underneath the oven bottom, the upper row passes along the top of the oven, thus giving an efficient and uniform temperature throughout.

It may be supposed that to expose these tubes to the action of the fire would be a source of great danger, and that an explosion would be the inevitable result, as a matter of fact, the risk is more apparent than real, for although explosions do sometimes occur, they are comparatively rare, and in such cases, the quantity of water or steam contained in the tube is so small, that the risk of personal injury is not very great. The following extract from a report on an explosion by the Board of Trade, and the illustration, Fig. 16, which is a reduced copy from the said report, will convey some information and give a general idea of how the apparatus is constructed and the conditions under which it is worked.

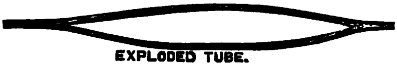


CROSS SECTION.





SECTIONAL ELEVATION.



EXPLODED TUBE.

Fig. 16.

BOILER EXPLOSIONS ACT, 1882 AND 1890.

REPORT OF PRELIMINARY INQUIRY.

(No. 488.)

EXPLOSION OF A TUBE IN A STEAM-HEATED OVEN AT MANCHESTER.

Description and Principal Dimensions of the Oven.

"The oven is styled Johnston's patent steam cooking oven, and its general arrangement is shown on the sketch attached. The exterior dimensions are 14 ft. 10 ins. in length, 10 ft. 7 ins. in width by 2 ft. in height at the front end, and 1 ft, 7 ins. in height at the back end. It is built with brick walls about 2 ft. thick, and contains one large baking chamber. The whole is heated by gas coke contained in two furnaces 2 ft. 8 ins. in length by $6\frac{1}{2}$ ins. in width, and about 1 ft. 9 ins. in height. The heat is transmitted to the baking chamber by two rows of hot-water pipes and the upper and lower flues. Each pipe when new is said to contain about 22 ounces of water and is hermetically sealed by the metal being folded over at the ends and welded. The pipes are of wrought iron, and their longitudinal seams are butt welded about 12 ft. long by $1\frac{5}{16}$ ins. external diameter by $\frac{1}{4}$ in. thick. There are 45 pipes in the lower row laid side by side, with an incline of about 5 ins. downwards at the furnace ends, and 21 of these pipes placed at a similar incline comprises the upper row. The ends of the upper row are carried across the top part of the furnace and the ends of the lower row serves as fire-bars. The oven was fitted with a mercurial thermometer at the side of the baking chamber and the necessary doors and dampers on the furnaces and ash-pits."

Nature of the Explosion.

One of the pipes in the bottom row, the position of which is marked on sketch attached, burst at the weld. The rupture in the pipe appears to have commenced at the end next the furnace and extended along the seam to a distance of about 6 ft. 6ins. in length. The pipe was fractured on both sides and was bulged out about 10½ ins., as shown on plate attached, the oven door was blown open, and two of the hot plates in the oven bottom were displaced."

Cause of the Explosion.

"The explosion was due to the pipe having been exposed to the intense heat of a coke fire long enough to generate within it a higher steam pressure than the seam of the pipe, owing to a defect in the weld, could withstand."

General Remarks.

"There are **14 ovens** of this type in use at the works, and are said to be well adapted for baking and cooking purposes when kept in order. Steam ovens similar in principle and construction to those above mentioned have, I believe, been in use many years, and no doubt their safety depends on the soundness of the welds and the materials in the tubes. The tubes, as before stated, are hermetically sealed at the ends and contain water, and when exposed to the intense heat of a coke fire, steam will be generated. The exact value of a welded seam is at all times uncertain, and in the tube that burst I think it must have been considerably below that of the solid metal. The oven was heated to 540° Fahrenheit, which is considered the best baking temperature, and when the tube burst the oven was ready to be charged with dough to be baked into bread. Some of the tubes in the ovens at the company's works have given trouble, and in order to ascertain their strength to resist internal pressure a few spare tubes were sent to the works of Sir Joseph Whitworth Co. to be tested."

SECOND REPORT.

GENTLEMEN,

WHITWORTH WORKS.

" Since my last report on Friday, 24th instant, I have caused two more pipes to be tested by hydraulic pressure, and they stood $2\frac{19}{20}$ tons or 6,608lbs. per square inch pressure; these tests are taken with the pipes cold. They did not show any signs of leakage anywhere; they appeared quite sound. "

Test by heating the pipes.

" I next caused a fire to be built at the end of a tube equal to the fire at end of oven at your place, but after firing for four hours could not raise the pressure in the pipe (at the end of which I had fixed a pressure guage) over 400 lbs. Afterwards I had a blast pipe put to the fire, and blew the fire up until the pipe burst at 3,920lbs. pressure, so that you may see the heat has a very material effect on the tubes. I return the burst pipe for your inspection. The water contained in three tubes was weighed as follows:

For each—12·6ozs., 5·4ozs., and 3·3ozs."

Respectfully yours,

(Signed) JOHN McFARLANE,"

Engineer to Sir J. Whitworth.

It will be seen that there is an element of risk despite the enormous strength of the tubes, and a word of caution may not be out of place to makers or users of this class of oven; the first named should not tamper with this kind of work, without having previously had considerable experience in high pressure work, and users should not entrust the work to unskilled or inexperienced persons.

CHAPTER IV.

THE LOW PRESSURE SYSTEM.

When we consider the immense advantages of this over all other systems of artificial heating, it is not surprising that within the last few years there should have been such an immense development. Its applications are so great and so varied, for horticultural buildings from the tiny greenhouse of the cottage garden to the huge conservatory of the nobleman or the long range of houses of the nurseryman or market-gardener, that no known system will compare with it; at the same time it is equally useful for private residences or public buildings, whatever their size or capacity. The heat can be readily distributed, easily controlled, and a more permanent and equable temperature maintained than by any other method. The following is a brief summary of the—

ADVANTAGES OF THE LOW-PRESSURE SYSTEM.

It can be applied to any description of building—public, private, horticultural, &c.

An even and equable temperature can be readily maintained.

The heat is easily distributed, regulated, or controlled.

Its first cost is lower than that of any other system.

Any kind of fuel can be used—coal, coke, slack, gledes, house-embers, &c. It is economic in consumption of fuel.

The heat, being mild and humid, rarely exceeds 190 degrees, and is agreeable and wholesome.

It may be fixed without skilled labour.

The risk of accident by fire is reduced to a minimum.

It is capable of easy manipulation and delicate adjustment, and it is simple, safe, and reliable.

To avoid failures it is necessary that we should clearly understand the motive-power that produces circulation, as without this there will be more or less uncertainty as to results, especially in the more complicated forms of its application.

THE CAUSE OF CIRCULATION,

though imperfectly understood by most people, and not unfrequently by those who are daily engaged in fixing hot-water apparatus, is the result of an immutable law of nature (the law of gravitation), and is so simple that with moderate care in its manipulation failures are next to impossible. A very slight experience suffices to show that a pipe taken from the top of a boiler and given a direct or gradual rise to the point farthest from the boiler, and then returned and connected into it at the bottom, will, upon the application of heat, cause the water to circulate; but how many hot-water fitters can give the reason why it does? or, more important still, tell when an apparatus will not act, and why it will not? It is not necessary that the water should boil, or even approach boiling-point, to cause circulation, as in a properly constructed apparatus the circulation commences soon after the heat is applied, and immediately the temperature is raised in the boiler.

In reply to the question, What causes circulation? you will frequently hear the reply, "Oh! as the water is heated it becomes lighter, and begins to ascend, and the colder water returns to take its place." It is a very common error to suppose that the circulation commences in the flow or up pipe, whereas it is just the reverse. The circulation is caused by the water in the return-pipe, which, owing to the difference in temperature, is heavier than that in the boiler, and consequently forces the hot-water, which is lighter, upwards, and thus sets the whole of the water in motion. Another reason equally erroneous is frequently given that "the tendency of hot-water is to ascend." If you take a vessel of hot water and fling it in the air it will ascend until the force exerted is spent; water from a street-main may be forced upwards by the pressure in the mains on to the roof of a lofty building, but it would evoke a smile if anyone asserted that it was owing to its tendency to ascend. A balloon when inflated with gas lighter than the surrounding air rises upwards, but the law of gravitation asserts itself immediately the gas escapes. Put two equal weights in the opposite scales of a balance, and they will remain stationary, but the moment you increase the weight in one balance, the opposite one goes upwards, not because its tendency is to ascend, but because it is forced up by the heavier weight in the opposite scale. The same rule applies in each case; the tendency upwards is in proportion to the increased weight or power exerted to force it upwards. Hence it is clear that the motive-power which produces circulation is the difference in weight of the two columns of water, which we will call the ascending and descending columns (see following table):—

TABLE No. 3.

Difference in Degrees Fahr. of the Two Columns of Water from 170° to	Difference in Weight of a Column of Water 12 inches high per Square Inch.
172 deg.	2·02 grains
174 ,,	4·06 ,,
176 ,,	6·10 ,,
178 ,,	8·16 ,,
180 ,,	10·20 ,,
182 ,,	12·26 ,,
184 ,,	14·32 ,,
186 ,,	16·39 ,,
188 ,,	18·45 ,,
190 ,,	20·53 ,,
193 ,,	23·64 ,,
196 ,,	26·74 ,,
199 ,,	29·85 ,,
202 ,,	32·06 ,,

From this table it will be observed that for every square inch area, the difference in weight (omitting the decimal) is one grain per foot vertical height of column for each degree of heat.

Now the area of a pipe, 2 inches inside diameter, is 3·14 inches.
" " 3 " 7·07 "
" " 4 " 12·56 "

So that the approximate motive-power may be readily calculated by the following

* RULE:—

The difference in degrees of temperature multiplied by the area of the pipe, and the product multiplied by the number of feet head of water, will give the approximate weight (in grains) that constitutes the motive power.

Example.—Suppose the water in the return-pipe to be 170 deg., and that in the flow pipe 178 deg., the difference would be 8 deg., the pipe, say 4 inch diameter, and the column two feet high from the bottom of the return pipe to the top of the flow-pipe.

The Area of 4-inch Pipe		Difference in temperature	Height in Feet		The Motive-power
12·57	×	8 deg.	2	=	201 grains.

So that in an apparatus with 400 feet run of 4-inch pipes there will be 200 gallons (2,000 lbs. weight) of water kept constantly in motion by the force of 201 grains or less than half-an-ounce; and when one thinks of the smallness of the motive power it is surprising that failures are not more frequent. Suppose in the same apparatus the height of the column be increased from 2 to 8 feet, the motive power will be increased fourfold, to 804 grains or under 2-oz. weight. Whether the pipes be 2 inches, 3 inches, or 4 inches diameter, the motive-power and the resistance are relatively the same, because the area of a 4-inch pipe is four times that of a 2-inch pipe, and the weight or bulk of water to be moved is also four times as great.

The motive-power may be increased in three ways:—(1) By increasing the height of the column; (2) by increasing the length of the pipes, and thus increasing the difference in temperature; (3) by using pipes smaller in diameter, and thus giving more cooling-surface in proportion to the quantity of water contained therein. It is impossible to draw a hard-and-fast-line that would be universally applicable, because every building must be treated on its merits according to local circumstances and surroundings. For instance, there are many places where a deep stoke-hole would be impracticable, owing to the damp nature of the ground, and where even the depth of a few feet would allow the water to rise above the fire-bar level and put out the fire. Again, many places require to be heated, where, owing to their construction, a small head of water is imperative. The length of pipes cannot be increased *ad libitum;* they should be proportionate to the cubical capacity of the room, and the temperature required.

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* This Rule would not apply in all cases; in lower temperatures (say usual 50 deg. to 100 deg.) it would vary considerably. As, however the from working temperature is from 160 deg. to 200 deg., it will be found sufficient for ordinary use.

THE BEST METHOD.

Where practicable the best way to ensure a rapid circulation is by increasing the height of the two columns. Some discretion should be exercised to avoid the opposite extreme, and so put an unnecessary strain upon the various parts of the apparatus. (See head or pressure of water.) The third suggestion for increasing the motive-power—viz., by using pipes of smaller diameter—is open to objection if carried beyond certain limits. In the first place, the smallest hot-water (cast) pipes usually made are 2 inches inside diameter, and if smaller sizes are required wrought tubes are substituted. This adds to the first cost, and also increases the friction, which will in proportion retard the circulation. (See sizes of pipes and the relative friction in Table No. 4, taking the 4-inch pipe as the unit.) (From Hood.)

TABLE No. 4.

RELATIVE FRICTION OF WATER IN PIPES.

Diameter of Pipe...	4 Inches.	3 Inches.	2 Inches.	1 Inch.	½ Inch.
Friction	1	1·3		4	8

Taking the 4-inch pipe as the unit, and the same velocity in all cases, it will be seen that the friction of water passing through a 1-inch pipe is four times, and the ½-inch eight times that of the 4-inch. It is sometimes necessary to dip pipes under doorways, &c., (and this should be done only in cases of absolute necessity), or to fix radiating pipes below the level of the boiler, and when such obstructions to circulation have to be overcome an increased height of column is imperatively required. This will be the more readily understood by referring to the following illustrations (which are taken from Mr. Box on "Heat"):—

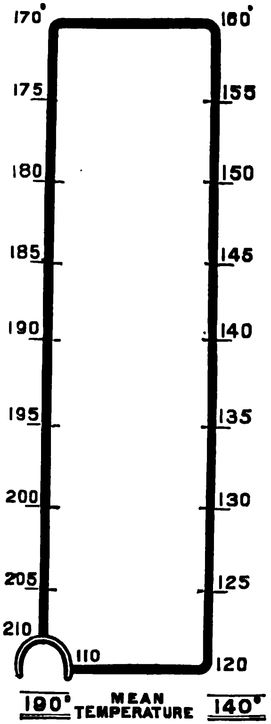


Fig. 17.

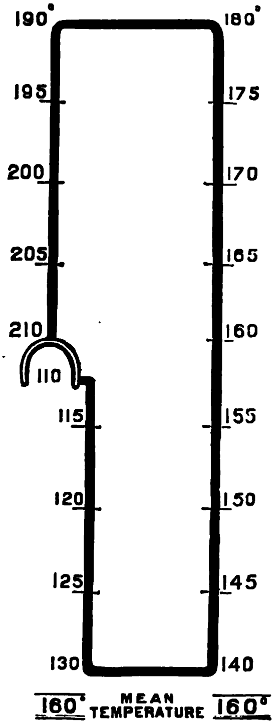


Fig. 18.

Fig. 17 shows the boiler placed at the lowest part of the apparatus. In Fig. 18 it is midway between the highest and lowest point. The water in each case is supposed to leave the boiler at 210 deg. and return at 110 deg. It will be observed in Fig. 17 that the mean temperature of the ascending column is 190 deg., and that of the descending column 140. deg. The difference in the specific gravities caused by the difference of temperature (50 deg.) will be the motive-power. In Fig. 18 the mean temperature of each column is the same (160 deg.); therefore, the weights being equal, there will be no circulation.

As already explained, the power which produces circulation is the difference in weight or specific gravity of the two columns. It therefore follows that any means by which that difference may be increased will add to the rapidity of the circulation and the efficiency of the apparatus. The following illustrations will, perhaps, make this more clear.

In Fig. 19 the motive-power will be the difference in weight of the two columns A F and C D. Let us suppose the pipes to be 4 inches diameter, length of flow-pipe A C to be 50 feet, the height of column A F to be 2 feet, and the water to lose 5 deg. of heat in passing from A to C; according to the foregoing rule the motive power would be 125 grains.

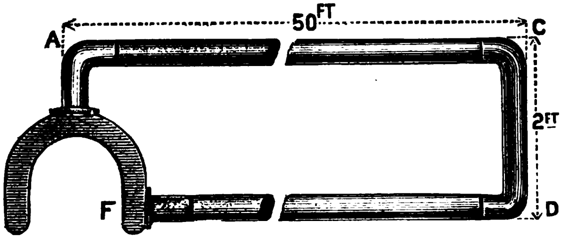


Fig. 19.

If the height of the column A F be increased to 4 feet, or the length of pipe A C be extended to 100 feet, the motive-power will in either case be doubled. It may not, however, be convenient to alter the arrangement in this manner, and the motive-power may be increased in another way, which would in many cases be found practicable and convenient.

If the water loses 5 deg. of heat in travelling from A to C, it will lose another 5 deg. in returning from D to F, which would not affect the circulation, because the water has reached its lowest point at D, so that the cooling surface between D and F is so much loss of power. Now, suppose the pipe D F be returned on the same level as A C, the water cools 10 deg. before its final descent, which will in like manner double the velocity of circulation. Or the return-pipe may be put vertically immediately under the flow (see Fig. 20), instead of side by side, and so cool the water as much as possible before the final descent F G.

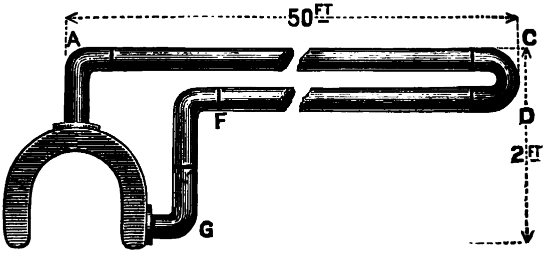


Fig. 20.

And in the simpler forms of apparatus this arrangement is about the best, and will generally be found applicable and convenient. It is not necessary (and, in fact, would be next to impossible) to determine the absolute minimum height at which the flow and return pipes should be inserted in the boiler; in the shallowest forms a height of 8 or 9 inches may usually be obtained, and so exceedingly feeble is the power required that this small head of water will ensure a good circulation in any quantity of pipes that the boiler is capable of heating, providing there are no dips or obstructions, especially if fixed as illustrated in Fig. 20.

When a dip is absolutely necessary to cross a doorway or other obstruction, and when a sufficient head of water cannot be obtained to create circulation, the difficulty may be overcome by extending the flow-pipe before making the dip (which should be in the return-pipe), and as near as convenient to the boiler.

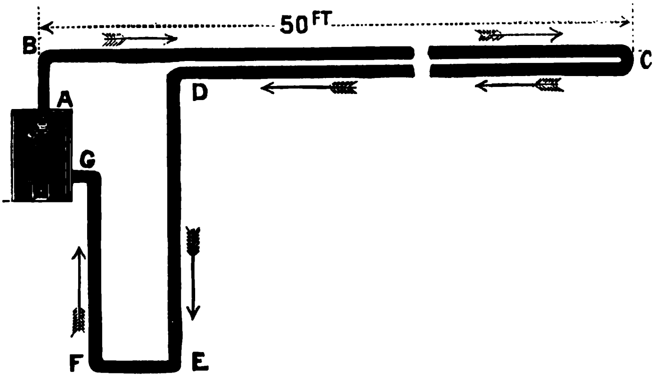


Fig. 21.

Showing circulation with dip in pipes.

Fig. 21 is an illustration of an apparatus in which the water circulates freely, although the rise A B is 17 inches, and the dip F G is 51 inches, *i.e.*, three times as much as the rise. This may appear paradoxical, when compared with Fig. 18, but it is easily explained. The water having travelled about 90 feet A B C D after leaving the boiler, is cooled considerably, and the difference in temperature is sufficient to overcome the counteracting effect in the pipe F G, the tendency of which would be to gravitate downwards, were it not for the difference in weight of the respective columns A B and D E. Now in the same apparatus without the dip (*i.e.*, similar to Fig. 20), the difference in weight is much less than in Fig. 21, the circulation being more rapid, and consequently more effective.

A summary of both tests is given below:—

TEST No. 6.		TEST No. 7.	
As Fig. 21 with dip. Flow A B rising 17 in.; return F G dipping 51 in.		As Fig. 20 without dip. Flow A B rising 58 inches.	
Greatest difference with heat rising	34 deg.	Greatest difference with heat rising	24 deg.
Average do.	29 „	Average ditto with heat rising	22 „
Average difference with heat falling	20 „	Average ditto with heat falling	9 „

In both tests the temperature approached boiling point, and were registered with a Fahrenheit thermometer, the globe of which was immersed in mercury, placed in direct contact with the pipe.

CHAPTER V.

HEAD OR PRESSURE OF WATER.

It has been stated that care should be taken to avoid unnecessary strain on the parts of an apparatus. It is amazing how many people have erroneous impressions on this subject. I have frequently heard the remark from intelligent and educated men, that there will be a good pressure because there is a large supply or reservoir, though placed only a few feet high. It should be clearly and distinctly understood that the *weight* of water is in proportion to its *bulk* or quantity, but the *pressure* depends on its column or vertical *height*; so that whether a supply-cistern holds 10 gallons or 10,000 gallons the pressure on the boiler and pipes will remain the same unless the height be increased. Neither is the pressure increased or decreased by the size of the supply pipe; the pressure from a pipe ½ inch diameter would be equal to one 4 inches diameter providing the vertical height be the same.

The pressure may be stated approximately as ½ lb. on every square inch of surface for every foot in height, so that a column 30 feet high would give a pressure of nearly 15 lbs. to the square inch. The actual pressure being 30 × ·433 = 13 lbs. pressure per square inch.

MEMORANDA–HYDRAULIC.

The freezing point under one atmosphere is 32° Far. or 0° Cent.
The boiling point „ „ „ 212° „ 100 „
The point of maximum density is 39·1° „ 4° „
The British Standard temperature 62° „ 16·66 „

at	32°	39·1°	62°	212° Far.
1 cubic in. pure water =	·03612	·036125	·03606	·03458 lbs.
1 cubic foot „ =	62·418	62·425	62·321	59·76 lbs.
1 lb. of pure water (7000 grains) =	27.684	27·680	27·727	28·978 cub. in.
1 Imperial gall. „ =	276·84	276·80	277·274	289·78 „

1 Imperial gallon = 10 lbs. = 277·274 cubic inches = ·16 cub. ft.
1 United States „ = 8·331 lbs. = 231· „ „ ·13667 „

1 cub. ft. = 62.3 lbs. = 6 232 Imp. gall. = 7·476 U. S. gall.
1 cub. in. = ·03606 lbs. = ·003606 imp. gall. = ·004329 U. S. gall.

Imperial gallons × 1·2 = U. S. gallons.
„ „ ÷ ·833 = „ „
„ „ × ·16 = cubic feet
„ „ ÷ 6·23 = „ „
U. S. gallons × ·833 = imperial gallons
„ „ ÷ 1·2 = „ „
„ „ × ·13367 = cubic feet
„ „ ÷ 7·476 = „ „

1 ton pure water = 224 gall = 35·84 cubic feet
1 cwt. „ = 11·2 „ = 1·792 „ „
1 cubic foot „ = 6¼ gallons nearly

1 ton of salt water = 217·95 gallons = 35 cubic feet
1 cwt. „ = 10·897 „ = 1.75 „
1 cubic foot „ = 6·4 „ = 64·05 bs.

1 cubic foot of ice at 32° = 57·96 lbs.

Expansion of water from 32° to 212° Far. = 1 in 23 or $4\frac{1}{3}$ %
„ „ in freezing = 1 in 12 or $8\frac{1}{3}$ %
„ linear of pipes from 32° to 212° = 1 in 900 or $1\frac{3}{8}$ in. in 100 ft.

A column of water 1 ft. high = ·433 lbs. pressure per square inch.
„ „ 33·947 ft. high = 14.7 lbs. „ „ = the pressure of the atmosphere at sea level.
„ „ 100 ft. high = 43·3 lbs. pressure per square inch.

Head of water in feet × ·433 or × 3 ÷ 7 = lbs. pressure per square inch
„ „ × 62·4 = lbs. „ square foot

Total superficial surface (in ft.) of closed vessel × ft. head of water × 62·4 = total pressure in lbs.
Total superficial surface (in in.) „ „ × „ „ × ·433 = total pressure in lbs.
Total superficial surface (in ft.) of open vessel × half the depth (in ft.) × 62·4 = total pressure in lbs.
Cubical contents (in ft.) of a vessel × 62·4 = weight (in lbs.) of water contained

Water is practically non-elastic, to reduce its bulk (by compression) $\frac{1}{24}$th part of its volume, requires a pressure of 15000 lbs.
Diameter of tube squared × ·034 = gallons per foot run
Area of tube (in inches) ÷ 23·1 = „ „
Diameter of tube squared × ·34 = weight in lbs. per foot run
Area of tube (in inches) ÷ 2·31 = „ „ „

AVORDUPOIS WEIGHT.

Grains	*Drachm*	*oz.*	*lb.*	*stone.*	*qr*	*Cwt.*	*Ton.*
$27\frac{11}{32}$	1						
$437\frac{1}{2}$	16	1					
7000	156	16	1				
			14	1			
			28	2	1		
			112	8	4	1	
			2240	—		20	1

SQUARE MEASURE.

Length × width = area or square measure
Length × width × height = cubical contents
Base × half perpendicular = area of triangle

USEFUL FORMULÆ RELATING TO THE CIRCLE.

Diameter × 3·1416 = the circumference
„ × 3⅐ = „ „
„ ÷ ·3183 = „ „
„ × ·8862 = the side of an equal square
„ ÷ 1·1284 = „ „
„ × ·886 = the side of an inscribed equilateral triangle
„ ÷ ·1547 = „ „ „ „
„ × ·707 = the side of an inscribed square
„ × the radius = „ „ „
„ squared × ·7854 = area of tube, cylinder or circle
Half the circumference × the radius = „ „
Circumference × ·3183 = the diameter
„ ÷ 3·1416 = „
„ × ·2821 = the side of an equal square
„ ÷ 3·545 = „ „
„ × ·2756 = the side of an inscribed equilateral triangle
„ ÷ 3·6267 = „ „ „ „
„ × ·2251 = the side of an inscribed square
„ ÷ 4·4428 = „ „
„ × ·15915 = the radius
„ ÷ 6·28318 = „
Area ÷ 3·1416 = the square of the radius
„ × 1·2732 = the square of the diameter
„ ÷ ·7854 = „ „
„ × 12·5663 = the square of the circumference
„ ÷ ·07958 = „ „

MEASURE OF CIRCLES AND ANGLES.

The unit is the degree, and is $\frac{1}{360}$th part of the circumference.

A circle contains 360 degrees °
1 degree = 60 minutes ′
1 minute = 60 seconds ″

A semicircle contains 180° or half the circle, = two right angles
A quadrant „ 90° or ¼th „ = one right angle
A sextant „ 60° or ⅙ „ and is an acute angle
An octant „ 45° or ⅛ „ = half a right angle
An octagonal bend „ 135° or ⅜ „ and is an obtuse angle.
A hexagonal „ „ 120° or ⅓rd „ „

The increased strain to which an apparatus will be subjected will be explained by the following illustration :—Take a plain saddle-boiler with 3 inch water-space and measuring 60 in. long by 21 in. wide by 21 in. high inside arch, the total plate surface of which would be 7,370 square inches. Suppose the head of water to be 30 feet above the centre of the boiler, 7,370 × 30 × ·433 will give 95736 lbs. or nearly 43 tons *pressure* inside the boiler, whereas the actual *weight* of water in the boiler would not exceed 3 cwt. If you increase the head of water to 60 feet the *pressure* will be about 86 tons. If you lower it to 15 feet it will be about 21½ tons, although the *weight* of water may remain the same in each case. From this example it will be apparent that in cases where a great head of water is necessary, as in lofty factories or in public institutions where the upper rooms have to be heated, the boiler, pipes, joints, and connections should be proportionate to the strain required. A head of 20 to 25 feet may be considered a safe maximum for most descriptions of ordinary hot-water apparatus, and in horticultural work it is very rarely necessary to fix the supply-cistern as high as this.

I would here mention another fallacy which is only too common, viz., that if the supply is placed a good height above the pipes it will improve the circulation, whereas, if the cistern is placed clear above the highest part of the circulating pipes it will act equally as well as if it were 20 feet above, and will at the same time reduce the pressure and strain to its minimum. After a boiler has been in use for a number of years it will scale and wear until it may be no thicker in places than a sheet of paper; it will be obvious that with a low pressure the life of a boiler may be prolonged for some years. It must not be supposed that there is great danger, even with 50 or 60 feet head of water, as a pressure of 30 lbs. on the square inch is not by any means an excessive amount. In a steam apparatus the danger is owing to its elastic or expansive force, but with hot water this force is so insignificant that there is practically no danger, excepting the risk of damage that may be caused by the leakage, or the expense or delay in repairing the damage. I do not infer that there is positively no danger. Accidents sometimes occur from explosion of kitchen boilers; these are invariably caused by stoppage in the pipes either by ice, scurf, or sediment, in which case the circulation is prevented, steam is generated, and the weakest part yields to the increased pressure.

These risks may, with ordinary care, be guarded against, and, taking all things into consideration, the immunity from risk is greater than by any other system of artificial heating.

CHAPTER VI.

VELOCITY OF FLOW OF WATER.

The Velocity of Circulation depends upon the motive power mentioned in Chapter 4, and also upon the size of the mains and the circulating pipes. In order that some idea of this velocity may be ascertained, it may be well to explain here the **theory** of **circulation,** or in other words, the **law** of **gravitation,** viz.: That all falling bodies gravitate with the same velocity, and descend through a definite space in a given time, hence the velocity of flow depends upon the difference in weight of the *up* and *down* columns of water, and the colder the water in the return pipe, the more rapid will be the circulation, the gravitating force being inversely proportioned to the temperature, *i.e.*, it is slower as the respective temperatures approach each other.

The motive power is the difference between the specific gravity of the water contained in the *up* and *down* pipes, and the velocity may be calculated (theoretically) by this difference. I don't like theories, they are not always confirmed by facts; and I believe in the old maxim that "an ounce of practice is worth a pound of theory." Nevertheless, the latter may be useful in shewing what results ought to be obtained under perfect conditions.

The following formula gives the method for ascertaining the velocity of a body or substance falling by gravitation.

$$V = 8\sqrt{H} \quad \text{or} \quad V = \sqrt{H} \times 8.$$

i.e., The Square Root of the height (in feet) × 8 = velocity (in feet) per second.

Now the *height* referred to here is not the height of the flow or up pipe, nor the height of the supply cistern, but the difference in weight of the water in the up pipe, and that in the down pipe.

If you refer to Table No. 5 column A gives the temperature, column B the expansion (in decimals of a foot) for a column 1 foot high; and column C the expansion (in inches) for a column 10 feet high. It will be seen that a column of water 10 feet high at 40 deg. temperature would, if raised to 212 deg. temperature, measure 10·4333 feet, or 10 feet 5⅕ inches, and the **height** referred to in the formula is the *difference* due to this expansion, and given in columns B & C opposite the respective temperatures.

TABLE 5.

EXPANSION AND WEIGHT OF WATER AT DIFFERENT TEMPERATURES.

Tem. Far.	*Expans'n of 1 foot T Box*		*Expansion for a 10 foot Column.*	*Weight in lbs. of 1 cubic foot.*		*Weight of 12 cubic inches.*		*Weight of 1 cubic inch.*		*Weight of 1 cubic inch.*
A	B *Feet.*		C *inches.*	D *lbs*		E *lbs.*		F *lbs.r*		G *·grains,*
40°	.0000	× 120=	.0000	62.42	÷144=	.4335	÷12=	03612	×7000=	252.84
52	.0005123	,,	.06147	62.40	,,	.4333	,,	.03611	,,	252.77
62	.001407	,,	.1688	62.36	,,	.4330	,,	.03608	,,	252.56
72	.002627	,,	.3152	62.30	,,	.4326	,,	.03605	,,	252.35
82	.004143	,,	.4971	62.21	,,	.4320	,,	.03600	,,	252.00
92	.0059	,,	.708	62.11	,,	.4313	,,	.03594	,,	251.58
102	.0079	,,	.948	62.00	,,	.4305	,,	.03587	,,	251.09
112	.01015	,,	1.218	61.86	,,	.4296	,,	.03580	,,	250.60
122	.01261	,,	1.513	61.70	,,	.4284	,,	.03570	,,	249.90
132	.01527	,,	1.832	61.52	,,	.4272	,,	.03560	,,	249.20
142	.01814	,,	2.176	61.34	,,	.4259	,,	.03549	,,	248.43
152	.02120	,,	2.544	61.14	,,	.4246	,,	.03538	,	247.66
162	.02443	,,	2.931	60.94	,,	.4232	,,	.03526	,,	246.82
172	.02788	,,	3.345	60.73	,,	.4217	,,	.03514	,,	245.98
182	.03148	,,	3.777	60.50	,,	.4201	,,	.03501	,,	245.07
192	.03526	,,	4.231	60.27	,,	.4185	,,	.03487	,,	244.09
202	.03922	,,	4.706	60.02	,,	.4168	,,	.03473	,,	243.11
212	.04333	,,	5.199	59.76	,,	.4150	,,	.03458	,,	242.06
	*									

* Remove decimal point one place to the right will give expansion (in feet) of 10 ft. column, and two places for expansion (in feet) of 100 ft. column.

The tables of expansion and weight, given by different authorities, are somewhat at variance, but the difference is so slight as not to materially affect the calculations.

Explanation of above tables, and the formula for ascertaining velocity of flow.

Difference in Expansion of water in flow and return (given in colum B) x ft. head of water (from return in boiler to top of Flow pipe) = **height,** then, The Square root of the height (in feet) x 8 = Velocity in feet per second.

To make this table, and the foregoing description perfectly clear, we will work out a few examples, the following five being calculated for various temperatures, but in each case, we assume the head of water to be 10ft.

EXAMPLES.

Temperature see column A	Expansion, see column B	Difference for each foot high.	Head of Water.	Height for Motive Power or Velocity.	Square root of Height	Velocity in feet per second.
Fah.			*Feet*			*Feet.*
Flow 102°	·0079	·0020	× 10 =	·020 sq. root of =	·14 × 8	=1·12
Return 92	·0059					
Flow 182°	·03148	·00360	× 10 =	·0360 ,, ,, ,, =	·19 × 8	=1·52
Ret'rn 172	·02788					
Flow 212°	·04333	·00411	× 10 =	·0411 ,, ,, ,, =	·2 × 8	=1 6
Ret'rn 202	·03921					
Flow 202°	·03922	·00774	× 10 =	·0774 ,, ,, ,, =	·278 × 8	=2·224
Ret'rn 182	·03148					
Flow 202°	·03922	·03132	× 10 =	·3132 ,, ,, ,, =	·56 × 8	=4·48
Ret'rn 102	·00790					

The above are theoretical velocities without any allowance for friction, and providing the pipes are of ample size in the bore, smooth inside, and free from right angles or square bends, tees, &c., we may take as an approximate velocity for a 10 feet column with 10° difference in temperature of, say 1 foot per second or 60 feet per minute, the probability is that it will be much slower than this, especially with long horizontal pipes, or if under the proper size in the bore.

The above examples are all for 10 feet head of water, which does not mean the height of supply cistern, as this would not affect the circulation if placed 50 feet above; but it means the height from the return pipe where it enters the boiler to the highest part of the flow pipe; and if this should be more or less than 10 feet, change the multiplier accordingly as in the following example which we will assume to have a head of 50 feet.

Temperature A *Fah*	Expansion B	Difference in each foot high.	Head of water. Feet.	Height for Motive Power or Velocity.	Square Root of Height.	Velocity in feet per second.
Flow 202°	·03922	·03132 ×	50 =	1·566 sq root of	= 1·25 ×	8 = 10 ft.
Ret'rn 102	·00790					

And for any other height or temperature the velocity may be readily ascertained in this manner.

The same result may be obtained by another method as follows: instead of taking the difference in expansion (in column B), take

The difference in weight of 12 cubic inches (as in column E) × 2·31 (feet of water in a pound) × head of water (in feet) = the height; then use the formula 8 √ H as before.

EXAMPLE.

Temperature A *Fah.*	Weight. as in column E *Lbs.*	Difference in Weight.		Head of Water *Feet.*	
Ret'rn 182°	·4201	·0033 ×	2·31 = ·00762 ×	10 =	·0762 height available: then
Flow 202	·4168				

The Square root of ·0762 ·276 × 8 = 2·2 feet per second velocity.

A third method of obtaining similar results is the following:—Height (in feet) × 32·2 (the velocity of a falling body in feet) per second × 2 and the square root of the product will be the answer.

EXAMPLE.

Height as given above.
·0762 × 32·2 × 2 = 4·90 square root of = 2·2 feet per second.

The first formula is the simplest and quickest, and will after a little study of the examples be tolerably clear.

CHAPTER VII.

LAWS OF HEAT.

Heat is transmitted in three ways—by *conduction*, as when the end of a short rod of iron is placed in a fire and the opposite end becomes warmed—this is conducted heat; by *convection* (means of currents), such as the warming of a mass of water in a boiler, furnace, or saucepan; and by *radiation*, as that diffused from a piece of hot metal, or an open fire. Radiant heat is transmitted like sound or light, in straight lines in every direction, and its intensity diminishes inversely as the square of the distance from its centre or point of radiation. A reference to the illustration (Fig. 22) will perhaps make this more clear. Suppose the distance from the centre of radiation to be 1, 2, 3, and 4 yards, the surface covered by heat rays will increase 1, 4, 9, and 16 square feet; the intensity of heat will diminish one, one-fourth, one-ninth, and one-sixteenth, and so on in like proportions until the heat becomes absorbed, or its source of supply stopped.

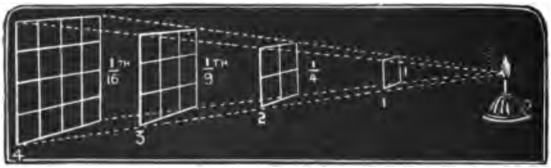


Fig. 22.

Whenever a difference in temperature exists either in solids or liquids that come in contact with or in close proximity to each other, there is a tendency for the temperature to become equalized; if water at 100° be poured into a vessel containing an equal quantity at 50° the tendency will be for the whole to assume a temperature of 75°, and suppose the temperature of the surrounding air be

30°, the cooling process will continue until the water and the surrounding air become nearly equal, the temperature of the air being increased in proportion as that of the water is decreased.

The heat generated by the fire under a boiler is transmitted to the water inside the boiler, when the difference in the specific gravities, or in other words, the cold water in the pipes being heavier than that in the boiler, sinks and forces the hot water upwards. This heat is radiated from the pipes,which are good conductors of heat, to the air in the room, and raises it to the required temperature.

That which absorbs heat rapidly parts with it rapidly, and is called a good conductor, and that which is slow to receive heat parts with it slowly, and is termed a bad conductor.

The following tables of conductivity, and of the radiating properties of various materials, may be of service.

TABLE 6.

Conducting Power of Various Substances.—Despritz.		Radiating Power of Various Substances.—Leslie.	
Material.	Conductivity.	Material.	Radiating Power.
Gold...	100	Lampblack ...	100
Silver	97	Water	100
Copper	89	Writing-paper	98
Brass	75	Glass	90
Cast iron	56	Tissue-paper ...	88
Wrought iron .	37	Ice	85
Zinc...	36	Rough lead ...	45
Tin	30	Mercury	20
Lead	13	Polished lead...	19
Marble ...	2·4	Polished iron ...	15
Fire-clay	1·1	Gold, silver ...	12
Water	0·9	Copper, tin ...	12

From the above tables it will be seen that water being an excellent radiator and of great specific heat, and cast iron a good conductor, these qualities, together with the small cost of the materials, combine to render them efficient, economic, and convenient for the transmission of heat.

HEAT.

What is it? A word freely used yet difficult to define. With a temperature of from 65° to 70° we frequently hear it remarked, "How hot this room is! it is insufferable." Water at the same temperature would be described as cold; a temperature of 90° in the shade we call "intensely hot." We should speak of water at this temperature as scarcely warm. A smith would rarely consider his iron hot if less than 800° (red heat), and would call it a good heat at 2,700° (welding). It would appear paradoxical to speak of heat and cold as synonymous terms, yet what we frequently call cold is only another term for a low degree of heat. The word "heat" is commonly used in two senses—(1) to express the sensation of warmth; (2) the state of things in bodies which causes that sensation. The expression herein must be taken in the latter sense. By adopting certain standards we are enabled to define, compare, and calculate, so as to arrive at definite results, hence the adoption of a standard unit of heat, unit of power, unit of work, &c.

The standard unit of heat is the amount necessary to raise the temperature of 1 lb. of water at 32° Fahr. 1°, *i.e.*, from 32° to 33°, and is called the British thermal unit.

SPECIFIC HEAT

is the amount of heat necessary to raise the temperature of a solid or liquid body a certain number of degrees; water is adopted as the unit or standard of comparison. The heat necessary to raise 1 lb. of water 1° will raise

	32	lbs. of lead	1 deg.
	31	lbs. of mercury	
	9	lbs. of iron	
	4½	lbs. of air	
or	2	lbs. of ice	

One unit of heat is capable of raising 772 lbs. weight one foot high, this is termed 772 foot pounds, and is the mechanical equivalent of heat.

A French Caloric (or unit) of heat is the quantity of heat required to raise 1 Kilogramme (2·204 lbs.) of water 1° Centigrade (1·8° Fahrenheit) in temperature, and is equal to 3·9683 British units.

Heat is measured by the use of thermometers, of which there are three distinct kinds, the Fahrenheit, Centigrade, and Reaumur.

The Fahrenheit thermometer is used in Great Britain and America, and ranges from Zero (0°) to 212° (boiling point), 32° being the freezing point.

The Centigrade is used in France and most parts of the Continent of Europe, the freezing point being Zero (0°) and the boiling point 100°; all temperatures below Zero being marked with the sign of minus or less, thus—for instance 5° below Zero would be marked --5°.

The Reaumur thermometer is used in Turkey, &c., Zero (0°) being the freezing point, and 80° the boiling point, temperatures below Zero are marked as in the Centigrade thus—5° or—10° means 5° or 10° below Zero.

Any temperature being given in either of the above-named thermometers, its equivalent may readily be found in either of the others, as follows:—

Degrees	Fahrenheit	− 32 × 5 ÷ 9	=	Degrees	Centigrade
"	"	− 32 ÷ 1·8	=	"	"
"	"	− 32 × 4 ÷ 9	=	"	Reaumur
"	"	− 32 ÷ 2·25	=	"	"
"	Centigrade	× 9 ÷ 5 + 32	=	"	Fahrenheit
"	"	× 1.8 + 32	=	"	"
"	"	÷ 5 × 4	=	"	Reaumur
"	"	× ·8	=	"	"
"	"	÷ 1·25	=	"	"
"	Reaumur	× 9 ÷ 4 + 32	=	"	Fahrenheit
"	"	× 2·25 + 32	=	"	"
"	"	× 5 ÷ 4	=	"	Centigrade
"	"	× 1·25	=	"	"
"	"	÷ ·8	=	"	"

TABLE 7.

Comparative temperatures of the Fahrenheit, Centigrade, and Reaumur Thermometers.

Fah.	*Centgde.*	*Raumr.*	**Fah.**	*Centgde.*	*Raumr.*	**Fah.**	*Centgde.*	*Raumr.*
212	100·0	80·0	132	55·5	44·4	52	11·1	8·8
210	98·8	79·1	130	54·4	43·5	50	10·0	8·0
208	97·7	78·2	128	53·3	42·6	48	8·8	7·1
206	96·6	77·3	126	52·2	41·7	46	7·7	6·2
204	95·5	76·4	124	51·1	40·8	44	6·6	5·3
202	94.4	75·5	122	50·0	40·0	42	5·5	4·4
200	93·3	74·6	120	48·8	39·1	40	4.4	3.5
198	92.2	73·7	118	47·7	38·2	38	3·3	2·6
196	91·1	72·8	116	46·6	37·3	36	2·2	1·7
194	90·0	72·0	114	45·5	36·4	34	1·1	0·8
192	88·8	71·1	112	44·4	35·5	32	Zero	Zero
190	87·7	70·2	110	43·3	34·6	30	—1·1	—0·8
188	86·6	69·3	108	42·2	33·7	28	—2·2	—1·7
186	85·5	68·4	106	41·1	32·8	26	—3·3	—2·6
184	84·4	67·5	104	40·0	32·0	24	—4·4	—3·5
182	83·3	66·6	102	38·8	31·1	22	—5·5	—4·4
180	82·2	65·7	100	37·7	30·2	20	—6·6	—5·3
178	81·1	64·8	98	36·0	29·3	18	—7·7	—6·2
176	80·0	64·0	96	35·5	28·4	16	—8·8	—7·1
174	78·8	63·1	94	34·4	27·5	14	—10·0	—8·0
172	77·7	62·2	92	33·3	26·6	12	—11·1	—8·8
170	76·6	61·3	90	32·2	25·7	10	—12·2	—9·7
168	75·5	60·4	88	31·1	24·8	8	—13·3	—10·6
166	74·4	59·5	86	30·0	24·0	6	—14·4	—11·5
164	73·3	58·6	84	28·8	23·1	4	—15·5	—12·4
162	72·2	57·7	82	27·7	22·2	2	—16·6	—13·3
160	71·1	56·8	80	26·6	21·3	Zero	—17·7	—14·2
158	70·0	56·0	78	25·5	20·4	— 2	—18·8	—15·1
156	68·8	55·1	76	24·4	19·5	— 4	—20·0	—16·0
154	67·7	54·2	74	23·3	18·6	— 6	—21·1	—16·8
152	66·6	53·3	72	22·2	17·7	— 8	—22·2	—17·7
150	65·5	52·4	70	21·1	16·8	—10	—23·3	—18·6
148	64·4	51·5	68	20·0	16.0	—12	—24·4	—19·5
146	63·3	50·6	66	18·8	15·1	—14	—25·5	—20·4
144	62·2	49·7	64	17·7	14·2	—16	—26·6	—21·3
142	61·1	48·8	62	16·6	13·3	—18	—27·7	—22·2
140	60·0	48·0	60	15·5	12·4	—20	—28·8	—23·1
138	58·8	47·1	58	14·4	11·5	—22	—30·0	—24·0
136	57·7	46·2	56	13·3	10·6	—24	—31·1	—24·8
134	56·6	45·3	54	12·2	9·7	—26	—32·2	—25·7

SPECIFIC GRAVITY

of solids, liquids, or gases, denotes the relative weight or density of same, distilled water at 62° Fahrenheit under the ordinary pressure of the atmosphere being the standard unit of comparison: if a given bulk of any substance is heavier than an equal bulk of water, its specific gravity will be greater, and if lighter, its specific gravity will be less than that of water. See Table 8, which gives the specific heat and the specific gravity of various substances, and the comparative weight of one cubic foot of each.

TABLE 8.

	Specific heat.	*Specific gravity.*	*Weight 1 cubic foot lbs.*
Water at 62° Faht.	1·0000	1·000	62·32
Air	·2380	·001293	·0807
Gaseous Steam	·4757	·00085	·05022
Hydrogen	3·4050	·0000895	·00599
Nitrogen	·2445	·001255	·07859
Oxygen	·2190	·00143	·08925
Aluminium Cast		2·60	159·
Alcohol	·6590	·825	49·3
Antimony	·0507	6·76	420·
Bismuth	·0308	9·86	617·
Brass	·0940	8 40	527·
Brickwork	·1918	1·77	112·
Cadmium	·0567	8·74	542·
Chalk	·2147	2·55	157·
Coal..	·2412	1·31	80·
Coke	·2030	·90	56·
Cobalt	·1069	8·55	532·
Copper	·0952	8·70	538·
Glass	·1770	2·45	156·
Gold	·0325	19·25	1102·9
Ice	·5040	·93	57·95
Iron. Cast	·1299	7·12	450·
„ Wrought	·1099	7·50	480·
Lead	·0314	11.30	708·
Marble, White	·2159	2·73	170·
Mercury, liquid	·0334	13.58	848·75
Nickel	·1087	8·30	513·
Platinum 212° Faht.	·0335	21·00	1340·
Silver	·0570	10·48	658·4
Steel	·1166	7·80	490·
Stonework	·1972	2·00	140·
Sulphur	·2026	2·00	125·
Tin	·0569	7·40	456·
Zinc	·0955	6·90	428·

CHAPTER VIII.

CAUSES OF FAILURE.

The word "failure" has an unpleasant ring, and when one meets with it the most philosophic thing to do is to find out the cause and apply the remedy. A few of the causes may be briefly summarised as follows :—

Air-pipes, want of, or improperly fixed.
Ball-cock, derangement of.
Boiler, improper shape, size, or construction.
Boiler, insufficient heating surface.
Boiler, water-space too large, or too small.
Boiler, incrustration or sediment in.
Boiler, not properly set.
Boiler, gas.
Chimney, too small in area, or not high enough.
Chimney, deposit of soot in.
Fire-bars, area not proportionate.
Flues, small or throttled, or deposit of soot in.
Fuel, improper kind of.
Joints, badly made, leakage, &c.
Pipes, insufficient quantity of.
Pipes, improperly fixed.
Pipes, too small in size.
Pipes, obstruction in, from air, dirt, ice, cotton-waste, shavings, flash of metal, &c.
Stoking, bad or careless.
Supply-cistern, overflow of water from.
Supply-cistern, (water in) getting hot, or frozen.
Valves, want of, or badly fitted.

I propose to treat these in alphabetical order as given bove ; and, as "prevention" is proverbially "better than cure," I trust the suggestions here given will be found useful in preventing some of the errors or causes of failure.

AIR PIPES.

Air-pipes or air-cocks should always be fixed on the highest parts of the circulating pipes; in some cases one only is required, but in others two, three, four, or an indefinite number may be necessary. Air-pipes are best, as they do not require attention. Air-cocks frequently get neglected, and the circulation ceases if the pipes become air-locked, they should be tested daily, to see that the pipes are all free from air. The specific gravity (or weight) of water being about 814 times greater than that of air, the latter is forced into the highest parts of the apparatus, and it is of the utmost importance that provision should be made for its free exit. Wherever the pipes rise from, and fall to, the main pipes, an air-pipe is necessary in every instance; or if a number of coils are taken from and rise above the mains, or if pipes are dipped under doors, &c., all the highest points should be provided with air-pipes.

The specific gravity of air being so much lighter than that of water, it is readily displaced, so that only pipes of small diameter are necessary; ¼-inch iron or ⅜-inch copper or compo tubes are sufficiently large; they are not very liable to get stopped, and are neater in appearance than larger pipes. Air-pipes should always be carried above the level of the supply-cistern, and where convenient, should then be taken through a wall to the outside, taking care that the mouth is turned down or left horizontal; if turned upwards it is likely to get stopped by dirt, leaves, &c. Air-pipes should always be carried above the level of the supply-cistern before being carried to the outside, otherwise they are liable to be blocked with ice, which not only splits the pipe and causes a leakage when a thaw sets in, but the apparatus will be rendered ineffective unless the air can be liberated.

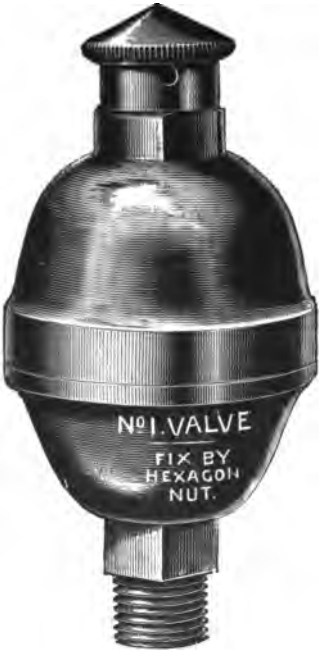


Fig. 23.

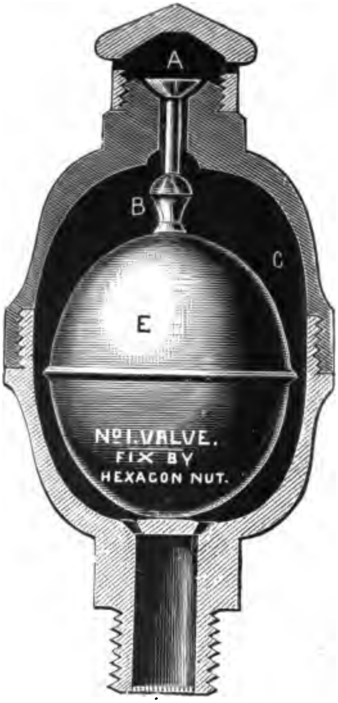


Fig. 24.

AUTOMATIC AIR-VALVE.

Figs. 23 and 24 are full-sized illustrations of Shields' Patent Automatic Frictionless Air Escape Valve and Section. The No. 1 pattern is intended for use where air pipes or air cocks would be either objectionable or inconvenient. To insure efficiency they require a head of water of 6 ft. or upwards. There are thousands of them in use, and they have undoubtedly supplied a trade want.

The No. 2 pattern, which is not illustrated here for want of space, comprises a No. 1 air valve with an adjustable spring safety or water escape relief valve combined. Its object is to prevent damage by frost to boiler or pipes that have through negligence been hermetically sealed with a plug of solid ice. The Manufacturer contends that a valve placed on the boiler, or the flow pipe near the boiler, will under such circumstances relieve the pressure in case the fire is started, and thus prevent the damage often caused to boiler, pipes, coils, &c.

Now, whilst respecting his opinion, I think there is a grave element of doubt, and should consider it dangerous to trust this (or any other) valve, when an apparatus is frozen up solid, and the fire started. The mischief is caused by the frost, *i.e.*, by the expansion of water into ice, the thawing only discovers the extent of the mischief, the melting of ice by hot water inside the pipes is very slow, and with a moderate fire steam may be generated and burst the boiler, thus adding a risk of danger to personal life and property that would not exist from the effect of freezing alone. Again, the neck of the valve is so small that it would be first affected by frost, and if only a few feet distant from the boiler, it would be possible to burst an apparatus before the plug of ice would be thus thawed. Safety should be the first consideration, and when any apparatus is frozen, the part affected should be located, taken to pieces and thawed, or the fire should not be started.

The No. 3 pattern carries in concentric combination two valves, an Adjustable Spring Safety Valve about $\frac{5}{8}$ in. diameter, designed to prevent the bursting of boiler, cylinder, or other bath apparatus, and a double action Anti-vacuum valve which admits air into any closed pipe, cylinder, or other vessel, to prevent a vacuum being formed when steam or vapour is generated, and suddenly condensed in the upper pipes or cylinder, subsequently, as the vessel again fills with water, the valve remains open, ejects the air from the cylinder, &c., and then closes to prevent the water passing out.

All the above valves have been in use for some years, and are considered useful requirements of the trade.

BALL COCKS.

Where large quantities of hot water are frequently drawn off, as for kitchen, scullery, or bath purposes, a ball-cock should always be fixed in, and near the top of the supply-cistern, allowing a space of about two inches clear from the water-level to the overflow-pipe. In a circulating apparatus used for heating purposes only, and not for hot water supply, the waste of water (providing there is no leakage) is so slight that a ball-cock is not necessary, especially for a small apparatus; but for any large apparatus it is desirable if a water-supply is convenient to hand, and it should be placed low, so that the ball will touch the bottom of the cistern when it falls. This will allcw room for expansion as the water becomes heated. Ball-cocks sometimes get deranged, stick when open or when shut, or the faces require to be renewed with leather, rubber, or other material; they ought to be periodically examined to see that they are in proper working order.

CHAPTER IX.

BOILERS.

It is not my intention to puff up any one boiler to the exclusion of all others; the variety, size, shape, design, and construction, are almost endless. I cannot pretend to mention, much less to illustrate, a tithe of them; a few of the best known forms and designs only are illustrated, so as to make the description clear.

The heating powers of most boilers are *mis*-calculated on the basis given by Hood, viz.: "that one superficial foot of direct heating surface will heat 50 ft. of 4 in. pipes," and this is the rock on which nearly all the boiler makers have stranded. I have known hundreds of instances where this mischievous basis has led to much trouble, disappointment, and expense, often resulting in complete failure, when the apparatus in every other respect would have been a complete success.

Boiler makers have vied with each other in measuring every inch of available surface, and putting the highest possible value, so as to give a large "*approximate* heating power" out of all proportion to the *actual* work demanded. The true test is not—How much piping will a boiler heat with clean flues, good fuel, and frequent attention? but—How much heating surface can be maintained at a fair temperature during a frosty night when the fire is banked up for 10 or 12 hours? To do this the "approximate powers" in most cases should be reduced one-half. I have known cases where boilers estimated to heat 3,800 ft. of pipes would not with the best of firing efficiently heat

2,000 feet. This is a hard saying, and is little short of a scandal. It is high time that all boiler makers revised their lists, giving the *actual* work that each boiler would do without excessive firing or special attention, bearing in mind that all boilers set in brickwork lose much of their efficiency after a year or two of work, owing to soot, dust, scale, and deposit.

How many thousands of boilers have had to be replaced before they are half worn out from this cause? Is it not to the interest of all concerned, the producer or manufacturer, the Architect who recommends, the Engineer who erects, and the Client who pays, that the work should be a complete success when carried out?

Work of any description when completed to the satisfaction of the client is a standing advertisement, and is the best recommendation one can have; better allow an order to pass, than carry it out in a manner that will bring only discredit.

Since writing the above I notice that Messrs. Hartley and Sugden have had the courage to issue a catalogue giving in one column the *approximate* heating powers (as in previous lists), and in a second column the *actual* heating powers, and whilst congratulating them upon the course they have adopted, which is a step in the right direction, I think the heating powers of some of the boilers may be still further reduced with a nearer approach to accuracy.

I had partially prepared a list of the actual heating powers of various boilers for a new catalogue now in the press. Some of them are very near to those given by Messrs. Hartley & Sugden, but others are from 10 per cent. to 20 per cent. lower; it would be a great advantage both to boiler makers and users, if a few of the leading firms would have a conference, and decide upon a new standard list, to be adopted by the Trade generally. Many persons imagine that a larger boiler means a greater fuel consumption, whereas the results are the exact opposite, the extra cost of a boiler a few sizes larger will often repay the first cost 50 times over in the fuel saved during the life of the boiler.

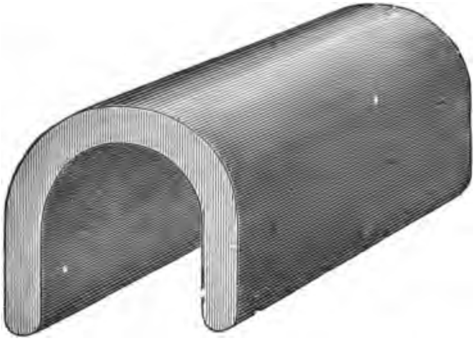


Fig. 25.

WROUGHT WELDED PLAIN SADDLE BOILER.

The plain saddle-boiler (Fig. 25) has long been in popular favour, and will doubtless hold its own for many years. It has many points to commend it. Its first cost is low, it is simple in form, and has no complications; it presents a good amount of heating-surface, and when properly set, is about as good a boiler as you can get for quantities of, say, 100 to 800 feet of 4-inch pipes, and, with a small water space (2 inches to 3 inches), may be considered a fairly economic boiler. It has ample fuel-space, so that the fire may be raked to last through the night (an essential feature for horticultural work). With saddle-boilers, or in fact any boilers that have to be built in brickwork, it is important that as much as possible of the boiler surface should be exposed to the flame, and not buried in brickwork. It is frequently the case that an apparatus with the pipes properly fixed, and the various parts of the apparatus well proportioned, proves a complete failure from this cause. Several instances have come under my own personal supervision where, with forced firing and good fuel the pipes could not be warmed, and after the boiler has been re-set, a good temperature could be maintained with the commonest fuel.

Boilers are made of cast iron, wrought iron riveted, wrought welded, and sometimes of copper. The wrought welded, being lower in price, have almost superseded the riveted boilers, especially the smaller sizes, from two feet to five feet long, but when exceeding five feet in length I should give riveted boilers the preference, as they are stronger, more durable, and can be repaired in case of waste, wear, or fracture.

For a large head of water, say forty feet and upwards, boilers circular in form, such as the "Vertical," "Trentham," "Titan," "Excelsior," &c., are best; they stand the strain better than boilers with large flat surfaces, and when subject to pressure of this kind riveted boilers are more reliable than welded.

CAST BOILERS

are not so liable to corrosion or incrustation, and, under favourable conditions will last longer than a wrought boiler. They are liable to fracture by sudden contraction of the metal, which may be caused by a sudden draught of cold air on some portion of the boiler when working, or, if sediment deposit is lodged in places acted on by the flame. When made with good metal, and of uniform thickness, fractures are exceedingly rare. The life of a wrought boiler is from ten to twenty years, and of a cast one from fifteen to thirty years. If there is an excessive amount of deposit, either wrought or cast boilers will give out in a much shorter time. Cast boilers cannot be made in the same variety of forms as wrought. Their principal forms are saddle, conical, tubular, or built up in sections.

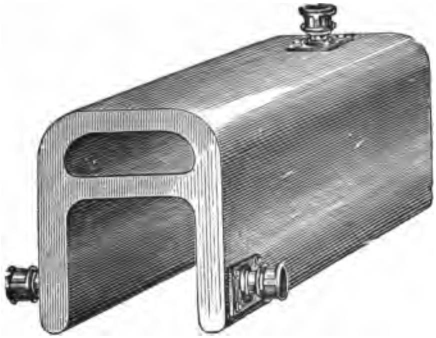


Fig. 26.

CHAMBERED BOILER WITH TERMINAL END AND RETURN-FLUE.

"Chambered" boilers, with terminal ends, (as Figs. 26, 27, &c.,) and one or more return flues are suitable for quantities of 800 to 2,000 feet of 4 in. pipes; the effective heating surface is much greater than that of a plain saddle boiler of equal length, and where space is limited, this is often a great convenience; after the flame has travelled three times the length of the boiler, (see Fig. 27) the *outside* heating surface is of little value, especially when coated with soot and ashes, which occurs after a few months use; the large flat surfaces are not favourable for a head of water of more than 20 to 30 ft., and if a greater head than this, they should be made of ⅜ in. plates, and the sides stayed with rivets to withstand the increased strain.

I have known many instances where the expansion and contraction have, after four or five years use opened the weld, and this is very disappointing and occasionally necessitates the introduction of a new boiler.

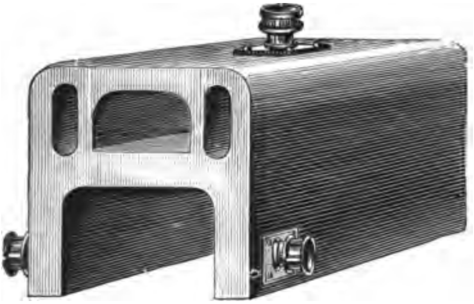


Fig. 27.

CHAMBERED BOILER WITH 3 RETURN FLUES.

For heavy work a boiler that presents a large amount of direct heating-surface, in a manner that the flame impact can be so intercepted as to spend its force before it gets into the chimney, or flues leading to the chimney, will be found most economical.

The "Trentham" is a form of boiler that has some important points in its favour; the circular form enables it to withstand a greater pressure, the sediment is deposited below the return pipes, and underneath the fire-bar level; this reduces the tendency to fractured plates owing to mud deposit, the heating powers of these (and in fact of most other boilers) are very much over-estimated. The heating surface of the upper half of the inner tube or fire-box is very effective, the lower half is of little value. The introduction of cross tubes and check end increase the efficiency and economy, as the outer surface especially with a slow draught is of little service.

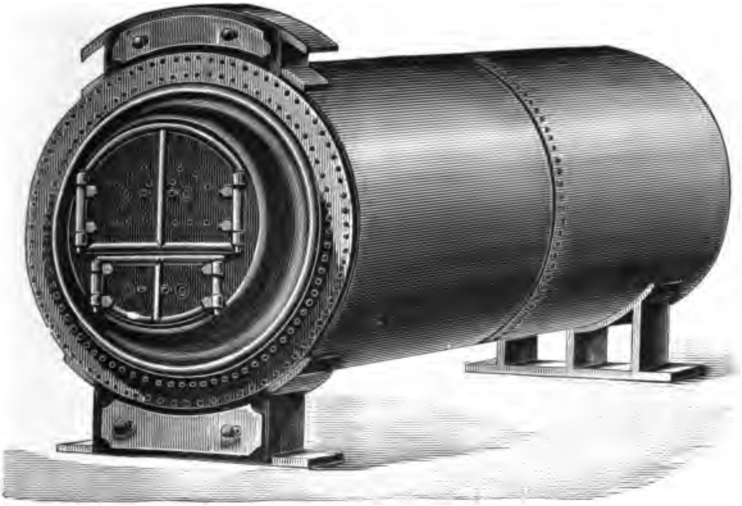


Fig. 28.

TRENTHAM CORNISH BOILER.

These boilers are used extensively by the London School Board, and are very suitable for their schools, and other similar buildings where they have lofty chimneys, and a good head of water.

I tested the powers of a "Trentham" 12 ft. long by 4 ft. diameter, with the flues winding underneath, and returning along the sides and top to the chimney, and afterwards altered the flue, giving a direct draught through the tube, (without any return flues) to the chimney, the difference in the results was scarcely perceptible; with the damper open, and full draught, the increased surface with the winding flues round the outer shell showed a slightly increased efficiency, but with a low chimney or insufficient flue area, the efficiency would not be perceptibly increased.

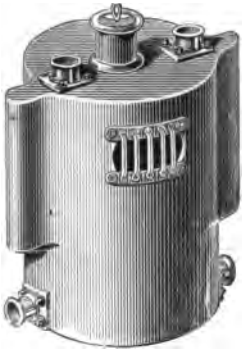


Fig. 29.

EXCELSIOR.

The foregoing remarks will apply generally to the "Excelsior" boilers; cross tubes would enhance their value, and when the diameter exceeds 4 ft., the ends or crown should be flanged and rivetted, thus increasing the strength and prolonging the life of the boiler.

There are many other forms and shapes of boilers that may be illustrated or described more fully did space permit, the following general description must however suffice: the various patterns of welded boilers for setting in brickwork are familiar to most of the readers, and descriptive illustrated catalogues can be readily procured by anyone desirous of obtaining them.

Horizontal Surfaces above the flame are the most effective. Vertical surfaces are valuable when the flame impact strikes against them, such as a terminal or check end. The vertical sides of boilers that have no waterway crown or cross tubes, to break up or absorb the heat rays, are less valuable. The efficiency also depends upon a proper mode of setting; this will be dealt with in a subsequent chapter.

Whatever the shape of the boilers, the most important point for economic working, is to have them well over their work, so that in severe weather, a little extra firing or attention will perform the work without forcing the draught to its utmost capacity.

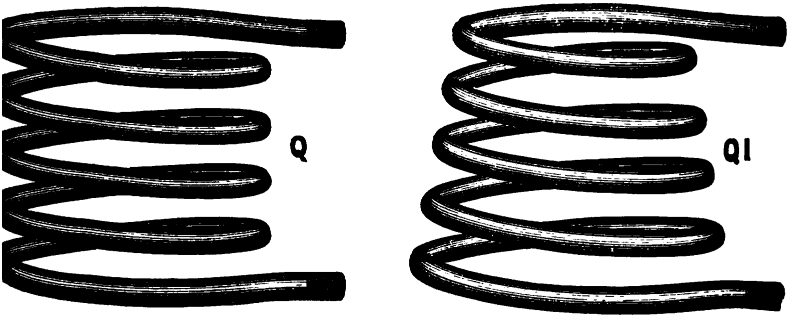
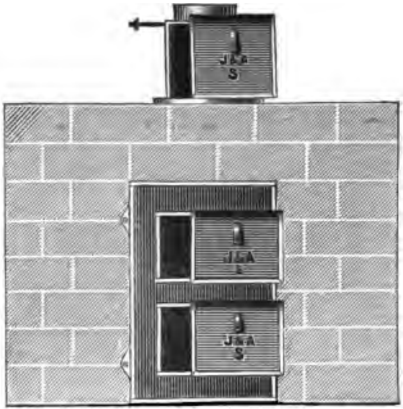


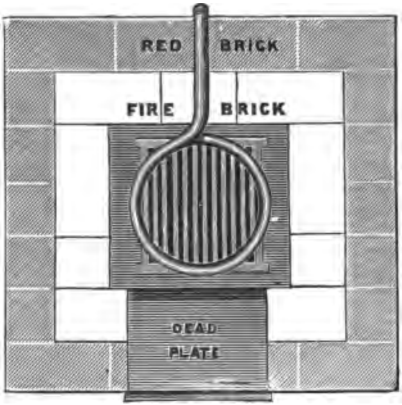
Fig. 30.

COIL BOILERS.

For small quantities of pipes, coils of wrought tubes as Fig. 30 are frequently used, the method of setting is shown in Fig. 31. The principal claims are:—First, they are low in price; second, the brick chamber will admit of sufficient fuel to last 14 or 16 hours without attention. The quantity of water contained is small, thus giving a rapid circulation, but this is not an unmixed advantage, as they are more liable to get foul with mud or sediment; for this reason they are not so suitable where quantities of hot water have to be withdrawn from the apparatus, or for heating large quantities of pipes.



FRONT ELEVATION



PLAN

Fig. 31,

SHEWING METHOD OF SETTING COIL BOILERS.

Cast iron boilers are made in various forms, such as the small self-contained boilers for Amateurs' greenhouses.

Larger sizes are made up of pipes or tubes that are connected either vertically or horizontally, with caulked socket joints; or with rubber or asbestos joints screwed together with bolts, &c. In some districts boilers of this description are extensively used for large ranges of pipes, the boilers being comparatively low in price for the amount of heating surface contained, although the cost of brickwork setting is proportionately high; many gardeners prefer them because they hold a large quantity of fuel, and require less frequent attention, but a strong point against them is they are generally extravagant in fuel, and require coke or anthracite coal, which is often difficult to get, or higher in price than coal or slack.

One frequently meets with people who have a preference for some particular make, or a prejudice against some other form of boiler, this often arises from the fact that they have had one that has given satisfaction, or another that has not been satisfactory, and they conclude that the construction, shape, or material, is at fault, whereas the real cause may lie in the size, or the setting, or defective draught. Whenever a preference or prejudice exists, the safest course is to allow a client to have his choice of boiler, and to suggest what size or mode of setting is most suitable.

Cast boilers with large flat surfaces are not desirable, as they are liable to fly from unequal expansion or contraction, but with small surfaces, providing the metal is equal in thickness throughout, they are less liable to scale or corrosion, and will last much longer than wrought iron.

Independent or self-contained boilers have some important points to commend them, and will doubtless come into more popular favour; the objection is sometimes urged that having a straight draught direct to the chimney, a great deal of the heat is thus wasted, but there is not so much force in this objection as may be supposed. A well-constructed self-contained boiler properly coated with non-conducting material will be found to give good results. Many boilers have been constructed for building in brickwork, with return flues, the flame being carried backwards and forwards two, three, or four times the length of the boiler, so as to abstract all the heat possible before passing it into the chimney. After watching closely the working of boilers of almost every conceivable shape, I venture the opinion that a moderately high temperature in the chimney does not necessarily mean greater waste, or a low temperature increased economy of fuel, and I could give scores of instances where, after dispensing with the winding flues of a plain saddle boiler, and substituting a straight draught as shown in Figs. 41 to 43, the effective power of the boiler has increased, while the consumption of fuel has been reduced.

Since writing the above I have confirmed the opinion already expressed by testing the respective merits of a "Trentham" boiler set in brickwork, and a wrought riveted vertical self-contained boiler, as illustrated in Fig. 32.

Both boilers are fixed at the same factory, doing the same class of work with the same kind of fuel; the pipes are the same size, fixed in precisely the same manner, in two drying stoves which are alike in construction.

The vertical boiler has less heating surface, is self-contained, does more work with less fuel, and gives better results all round, although the height and area of chimney and the draught are in favour of the "Trentham."

The proportions of both boilers and pipes are as follows:—

Trentham Boiler.	Vertical Boiler.
12ft. long by 4ft., outside diameter, 3ft. 6in. inside diameter, with check end;	6ft. high by 5ft. outside diameter, 5ft. 8in. high by 4ft. 6in. inside diameter;
3 Gallaway tubes. 7in. diameter;	4 cross tubes and 4 vertical tubes;
Plates ⅜in. thick;	Plates ⅜in. thick;
Heating 6,060 feet of 2-inch pipes	Heating 7,400 feet of 2-inch pipes
,, 180 feet of 4-inch mains	,, 250 feet of 4-inch mains
Slack consumption per week, 3¼ tons.	Slack consumption per week, 3 tons.

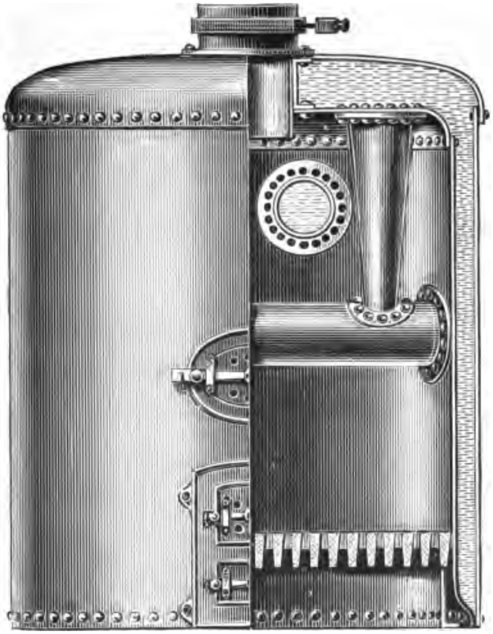


Fig 32.

VERTICAL SELF-CONTAINED BOILER.

The heating surface *inside* the "Trentham" is greater, and the *total* surface is more than double that of the vertical; the results go to prove that the shape or construction of the vertical is better calculated to absorb the heat from the fuel; that the radiant heat from the fire is much more effective, and that the power of a boiler is not necessarily proportionate to the amount of heating surface it contains. The waste heat passing from the vertical boiler into the chimney is much greater than that of the "Trentham," which shews that lowering the temperature by winding flues does not necessarily mean economy.

The direct heat from a clear fire is very effective; the spent heat from an indirect or winding flue is of little value, and causes a sluggish draught that leaves a coating of tar or soot on the boiler, thus reducing the effect of the flue heat and minimising the direct heat inside the boiler at the same time. If a lofty chimney is available a winding draught may be used with advantage, but with a low chimney it is a very questionable saving.

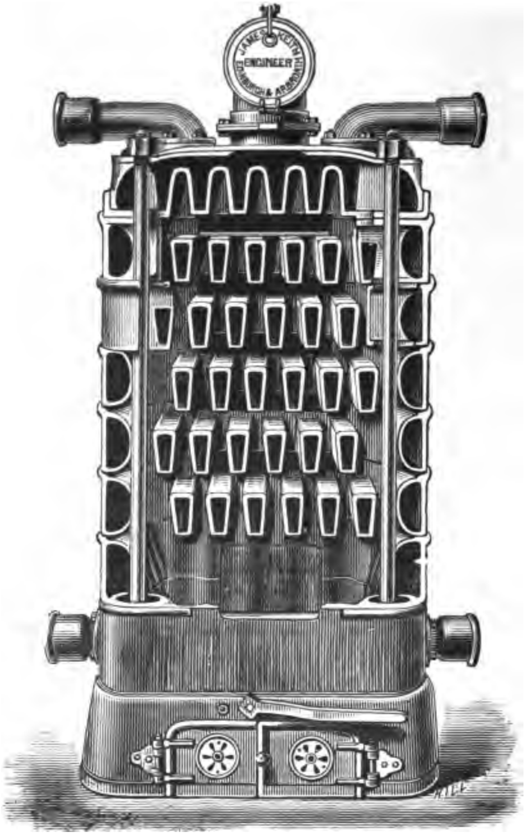


Fig. 33.

KEITH'S SECTIONAL CHALLENGE BOILERS (CAST IRON) have had a large sale; the sectional arrangement is very convenient for transit, for getting through narrow doorways, fixing in confined spaces, or for export. They have a large heating surface directly over the fire; they are well designed; the materials and general construction are excellent. The prices are rather high; they are adapted for coke or anthracite coal only; with ordinary coal or slack they soon get foul with soot. Owing to the difference in expansion of the cast iron sections and the long wrought bolts that screw them together, I have noticed many of them leak at the joints after a few years wear; in one case the leakage cankered away the sections and thus shortened the life of the boiler by several years. Leakages however slight should be stopped to prevent this mischief.

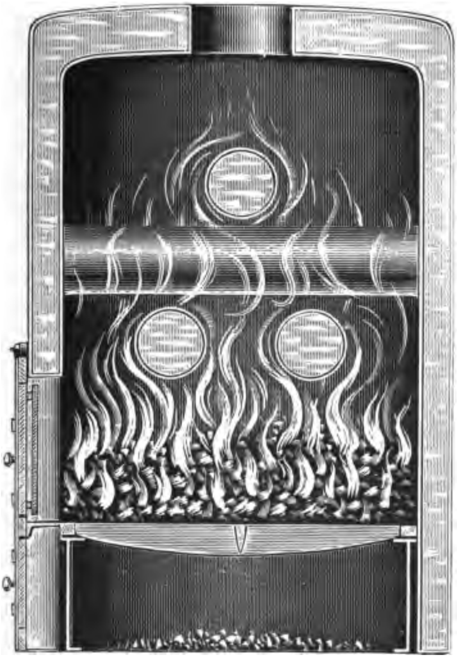


Fig. 34. (Section.)

The Titan Self-contained Boiler (Fig. 34) possesses many advantages.

It is **made** of **wrought** iron or **steel.** Requires **no brickwork** setting. Simple in construction, **powerful, compact,** neat in design, and occupies little space. Will stand heavy pressures, **100 feet head** of water if required. Free and **rapid** circulation. Large **fuel space;** may be banked up to last from **12 to 20 hours. No flues** to get **foul;** soot and ashes fall into the fire. Very **economic,** and will burn any description of **fuel. Specially** adapted for **hot water supply** for large Institutions. Mudlids fixed for **facility** of **cleaning** where the deposit is excessive. **Water space** being 10 or 12 inches below fire bars allows room for deposit, and thus **prevents** the **plates** from burning or cracking. Suitable for warming **large quantities** of water, such as **swimming baths,** &c. Shells are **rivetted** in large sizes, **No. 19 and upwards.**

I have fixed a large number of these boilers, and after the most severe tests, I can recommend them with perfect confidence. In many cases the substitution of these in place of other well-known boilers has resulted in a **clear saving** of from **30°/₀ to 50°/₀** of **fuel.**

In the "Titan" one Superficial Foot of surface is allowed for 25 ft. of 4 in. pipes. It is made in various sizes to heat from 400 to 7,000 ft. of 4 in. pipes.

Boilers with large water spaces are slow in action, and require more fuel. If the water space is too small, they are liable to be filled with sediment or deposit, and allow the plates to burn through, or the circulation may be impeded by choked passages. A small water-space and large heating-surface will give a more rapid circulation. For small boilers a 2 inch water-space, for medium boilers 3 inches, and for very large boilers 3 inches to 5 inches may be considered good proportions.

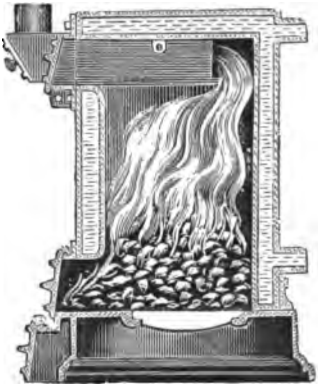


Fig. 35.
THE FINSBURY BOILER.

For small quantities, say 40 to 400 feet of pipes, self-contained or independent boilers such as the "Finsbury" or "Desideratum," will be found useful and convenient, and owing to the water-way crown, which receives the flame impact, they are more economical than the "Slow-Combustion," "Star," and other similar boilers which lack this important feature.

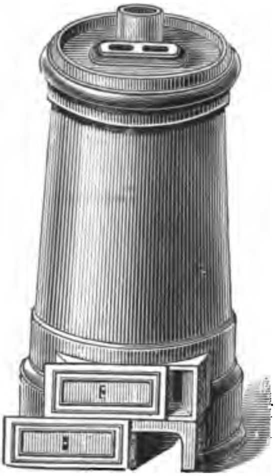


Fig. 36.

The Star Boiler (Fig. 36) is low in price, and beyond this, little can be said in its favour, although thousands have been sold. The heating surface being vertical is not favourable to economy, the flat cast tops are liable to crack, and the smaller sizes (10 ins. diameter) will not hold sufficient fuel for banking up at night, and if coke is used it clogs and sticks thus remaining unconsumed. A dome top and an *inside* diameter of at least 10 inches would be a great improvement to this boiler.

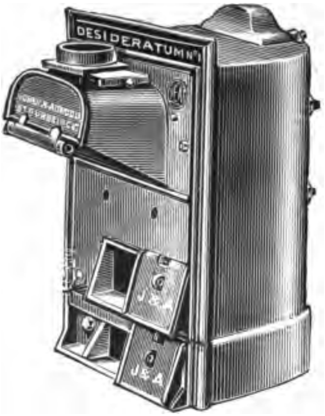


Fig. 37.
THE "DESIDERATUM" BOILER.

Independent Boilers are usually considered "tenants' fixtures," and are often preferred on this account, especially when there is a probability of the occupier removing to some other residence.

A great impetus has been given to the manufacture and sale of small greenhouses for Amateurs, by the introduction of small boilers specially designed for building in the side or end of the greenhouse; among the types of boilers referred to, probably the "Loughborough," "Horse-shoe," "Ivanhoe," and "Desideratum," are the most familiar, as these boilers have all had a large sale. The smaller sizes of the "Desideratum" boilers, Nos. 1, 2, and 3, are made of cast iron, the larger sizes, Nos. 4 to 9, are wrought welded, and are capable of heating from 200 to 600 ft. of 4 in. pipes; they are also well adapted for supplying hot water for baths, lavatories, and other domestic purposes.

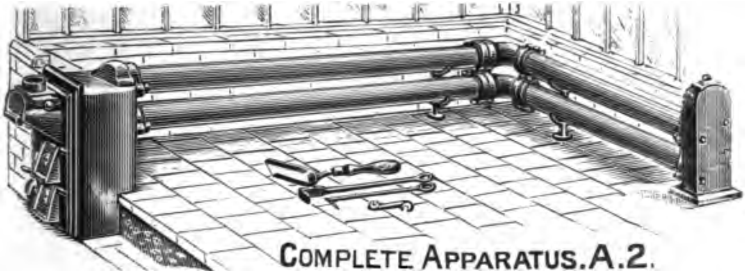

COMPLETE APPARATUS. A.2.

Fig. 38.

The "Desideratum" complete apparatus (Fig. 38) is a most convenient form of apparatus for heating small greenhouses, coachhouses, and other structures. The total height being only 20 to 24 inches, dispenses with the cost and inconvenience of a stoke-hole. It is economic in fuel, occupies a limited space, is low in price, has fuel space sufficient to last 10 or 12 hours, and is thoroughly reliable.

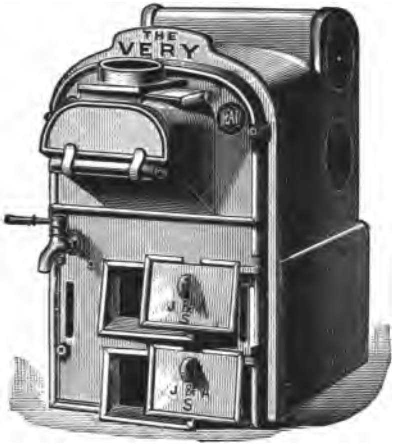


Fig. 39.
THE "VERY" BOILER.

The "Very" Boiler is a later introduction of a similar type, which contains some special features worthy of more than a passing notice. The object aimed at in designing this boiler has been to combine strength, efficiency, durability, and a neat appearance, thus giving a reliable boiler at a moderate price. The principal points are increased fuel space without increasing the height, the feeder, front plates, hot plate and flame plate can be easily replaced without emptying the apparatus. The air for combustion is heated by passing round firebricks on which the boiler rests before passing underneath the firebars, the combustion is rendered more perfect, the fire can be banked to last for 14 hours without attention, and all the fittings are strong and substantially made. The connections (any size up to 4 in.) can be taken off the right, left, or back of boiler, or from all three positions if so desired.

Important developments and great changes have been introduced during the last few years for producing a reliable apparatus for small greenhouses, &c., but a large field is still open. I think it highly probable that in the near future a gaseous fuel will be substituted for the coal and coke now in general use. A fuel known by the name of "water-gas" is now produced, which has important properties, both for lighting and heating purposes; it is said to be low in cost, to give out an intense heat, and to require little attention. A fuel of this kind, with a boiler specially constructed to produce the maximum results, would be invaluable for the purpose mentioned, and would, without doubt, command a ready sale.

CHAPTER X.

DUPLICATE BOILERS.

The fixing of boilers in duplicate so that either or both may be used jointly or separately is not always necessary, and in many instances would not justify the additional cost: there are however cases in which the system may be adopted with considerable advantage, and the extra expense would be more than justified. In the majority of cases where a breakdown or failure of the boiler occurs, it happens during severe weather, and at a time which causes the greatest amount of inconvenience and loss. How often does it happen that a range of glass houses, containing orchids, or other rare and valuable plants, is dependent upon a single boiler which has to heat from 2,000 to 5,000 ft. of pipes, the failure of the boiler at a critical time may in a single night result in loss or damage that is almost irreparable, besides the anxiety and trouble consequent thereon. I have known many such cases where independent boilers and pipes, petroleum lamps and other temporary expedients have been resorted to, until the boiler could be repaired or a new one substituted. The value of an additional boiler in duplicate in such a case can scarcely be estimated, and the first cost is a mere trifle compared with the advantages derived.

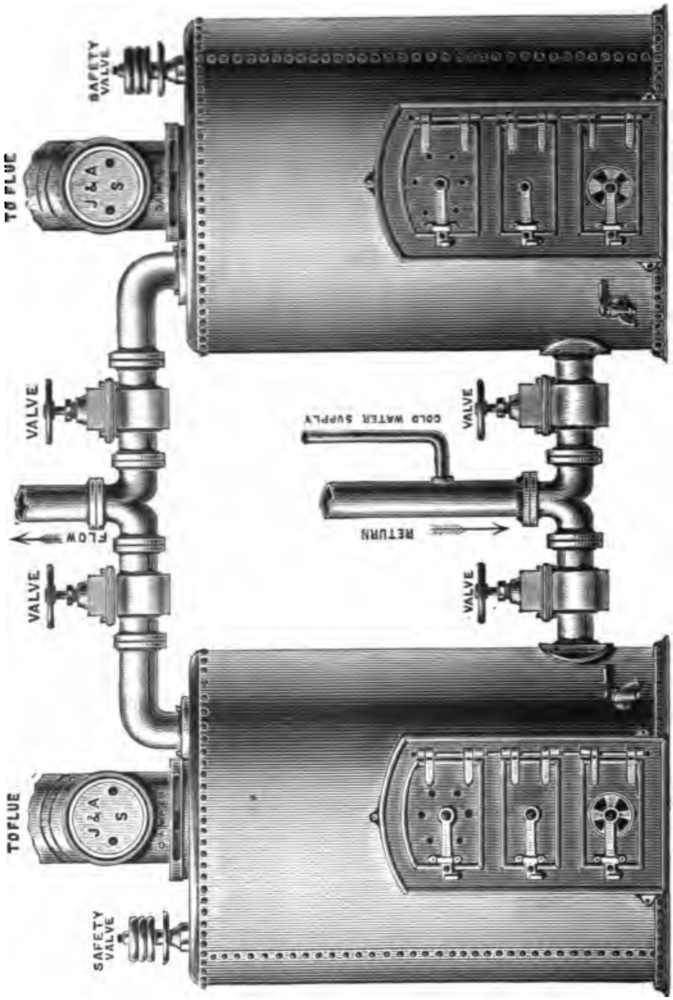


Fig 40.

The illustration (Fig. 40) shows an arrangement of two boilers in duplicate, with the necessary valves, &c., so arranged that either boiler may be used separately or both jointly, and importan advantages will result; the boilers should be used alternately, say for three or four weeks each during mild weather, and in severe weather the two boilers used jointly will prevent either from being over-worked or strained, and in most cases with economy of fuel also; forced work from any boiler always means increased fuel consumption. Wherever boilers are set in duplicate, the following points should be carefully observed:—

1. Each boiler should be sufficiently powerful to heat independently all the pipes that may be connected.
2. Screw down or perfect valves should be fixed on flow and return pipes of each boiler.
3. The supply pipe from cistern should be connected to each boiler, or to the return pipe near boilers.
4. An expansion pipe (about 2 in.) should be taken off the top of each boiler or off the flow pipe between boiler and valve, and carried up two or thre yards above the level of cistern to relieve undue pressure, or in case the valves should be inadvertently closed whilst boiler is working.
5. Expansion pipes when carried outside should be protected from frost.
6. In cases where an expansion pipe cannot be thus fixed, a safety valve should be fixed on each boiler instead.

The boilers illustrated (Fig. 40) are self-contained; boilers set in brickwork may be similarly fixed, but with duplicate boilers the points above-mentioned are most important.

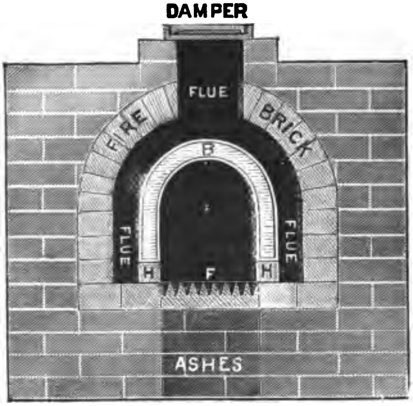
The duplicate system is especially recommended:—

1. For large Public Institutions where any stoppage would lead to great inconvenience.

2. Horticultural purposes where a number of houses are connected, especially when rare and valuable plants are at stake.
3. In all cases where the first cost is not a serious consideration, or where a stoppage would cause great loss, inconvenience, or discomfort.

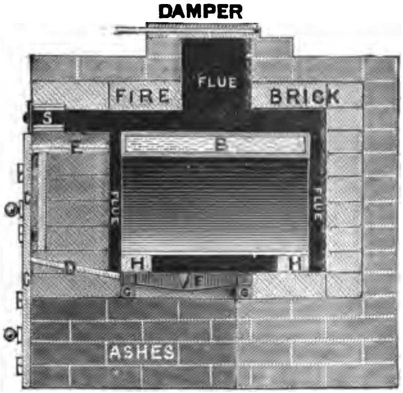
BOILERS (SETTING OF).

It is of the highest importance, if you are to get the best results that boilers should be properly set, and in country places it is a rare occurrence to meet with a practical bricklayer who understands how to set them. The direction of the flues may be varied to suit the position of the chimney, which may be at the front or back end of the boiler, but care should always be taken to fix soot-boxes in such positions that all the flues can be readily cleaned with a rake or scraper.



END ELEVATION IN SECTION
Fig. 41.

The illustrations (41 to 44) show the best way of setting small saddle-boilers (say, up to 48 inches long). The flame plays directly over the whole surface of the boiler inside and outside, the flues cannot get foul, they are easily cleaned, and the life of the boiler will be prolonged owing to its having a clear air-space all round it. The plates of a boiler are frequently corroded by moisture when and where they are in contact with brickwork, such as brick midfeathers, &c.

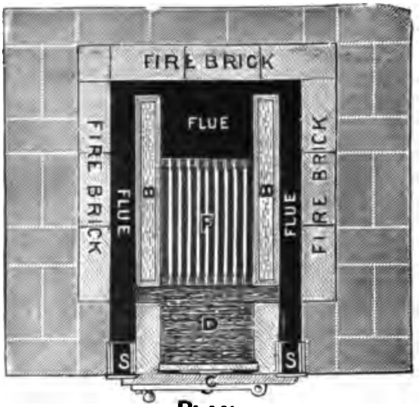


SIDE ELEVATION IN SECTION.
Fig 42.

BRICKWORK SETTING OF SADDLE-BOILER.

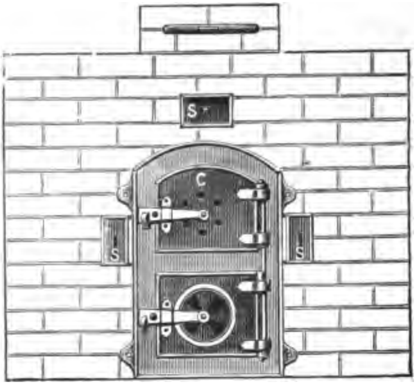
Scale ½ inch = 1 foot.

The boiler is placed upon four fire-bricks, the bottom of the boiler being about 2 inches to 2½ inches clear above the fire-bars; a clear flue-space is left at the front, back, and sides of boiler, so that it does not come in contact with any brickwork except the four bricks on which it rests. The flue at the front end should be 1½ inch, the one at the back about 2 inches, and the flues on sides and over top of boiler not less than 3 inches; the uptake to chimney is taken from (or near) the centre of boiler, and provided with damper. The whole surface inside and outside of boiler is thus exposed to the direct action of the flame, the flues are not so liable to get foul, and they are easily cleaned.



PLAN

Fig. 43.



FRONT ELEVATION

Fig. 44.

DESCRIPTION.

B Boiler | **C** Furnace-front. | **D** Dead-plate
E Bridge-plate | **F** Fire-bars | **GG** Bearers to carry fire-bars
HH Fire-bricks on which boiler is placed | **SS** Soot-boxes.

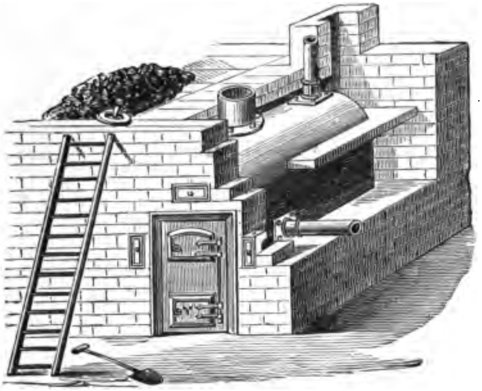


Fig. 45

BOILER SETTING WITH WINDING FLUES.

For setting saddle boilers over 4 ft. long, the perspective view shewn in Fig. 45 is perhaps more suitable, with winding flues passing underneath the midfeathers on sides of boiler, and returning over the top to the chimney; the sides and top flues should be 4 to 4½ inches wide, and 4 to 5 inches clear between the boiler and firebrick at back of ditto; the return flue openings between the front brickwork and the end of the midfeathers should be 12 to 18 inches long, according to the size of the boiler. Soot boxes should be placed so that all the flues can be readily cleaned.

GAS BOILERS.

Gas boilers, *i.e.*, boilers to be heated by gas, are made of copper and cast iron in several forms for heating small quantities of pipes, they save much trouble of stoking and frequent attention. For irregular work, as cooking, boiling water, &c., for short periods, gas is cheap and convenient; but for long-continued or constant work it is very expensive, as 1 lb. of coal is equal to 20 feet of gas.

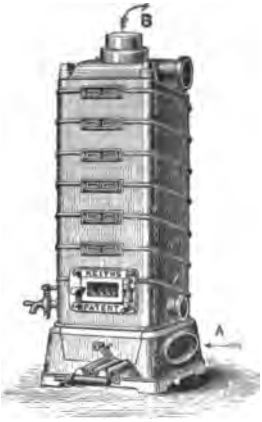


Fig. 46.

KEITH'S SECTIONAL CHALLENCE GAS BOILER.

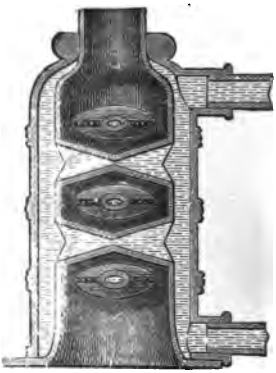


Fig. 47.

FLETCNER'S CROWN TUBE GAS BOILER.

Atmospheric burners are best for boiling or warming water, but the cold water constantly returning to the boiler creates a condensation from the plates of the boiler, which, if not provided against, is liable to drip on the burner and rust up the apertures. Twelve feet of gas per hour requires a flue 2 inches in diameter, and should not be carried further horizontally than 16 feet. Some atmospheric burners are liable to light back and ignite at the air inlet. This may be caused by a defective burner, or by carelessness in lighting, and produces a very disagreeable smell, and is less effective. The consumption of gas for a small greenhouse with a good boiler is in severe weather about 20 feet per hour.

I am indebted to Mr. Thomas Fletcher, of Warrington, for a copy of his small pamphlet entitled "Coal Gas as a Fuel." The following information and illustrations (Figs. 47 to 50) are taken (with his permission) from this useful little work.

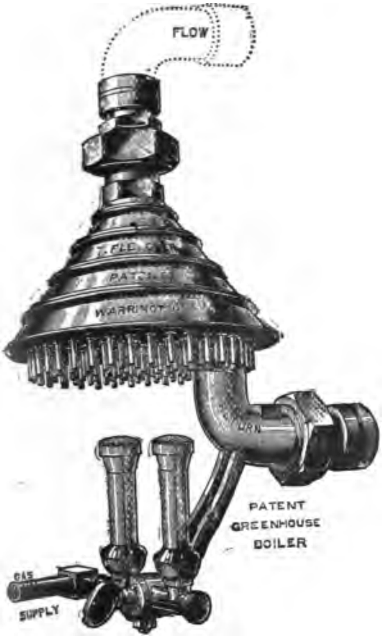


Fig. 48.

FLETCHER'S CIRCULATING BOILER.

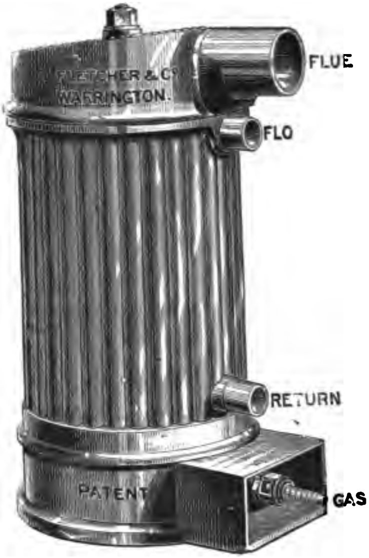


Fig. 49.

FLETCHER'S STUDDED TUBULAR BOILER.

"**It is essential** for healthy plant life that the heat of a plant house shall be fairly equal and steady, and it will therefore be easily understood that a stove in one spot cannot be satisfactory in any except the smallest conservatories or greenhouses, say under 10 ft. square. For these, there are two systems available, a warm air stove with a flue, or a condensing stove, which requires no flue. The products of combustion are seriously injurious to almost all plants unless the trace of sulphur invariably present is condensed, which can be done effectually with stoves which are designed for the purpose. If a stove is used with a flue this requires the same care and conditions in fixing as a circulating boiler, and the instructions for fixing must be carefully attended to. It is perhaps beyond human skill to make a flue or chimney in any position which shall be invariably satisfactory under all conditions of wind and weather, or we should have fewer smoky chimneys in houses built by experienced architects, but with the exercise of care and judgment the failures are very rare. It must be remembered that gas is too costly a fuel to use for large plant houses, but it will be found most satisfactory for small greenhouses and conservatories. The following figures are given from actual working results:—

A span-roof house, protected from north and east winds, size 20 ft. square and 12 ft. high to the ridge, requires an annual consumption of 34,000 cubic feet of gas to maintain a minimum of 45°.

A lean-to-house, 12 ft. square, 7 ft. high at eaves, 14 ft. at highest point, requires a consumption of 55,000 cubic feet per annum to keep a minimum of 50° in winter, and 60° in summer. The same house would probably require about 25,000 cubic feet to keep a minimum of 45°, and about 12,000 cubic feet for a minimum of 40°.

The reason for the extraordinary difference of cost for so small a variation of temperature is partly owing to the greater heat, but almost entirely to the greater number of days on which a fire is necessary to keep above the minimum. For every day on which it would be necessary to heat the pipes to a minimum of 40° it would probably be necessary to heat the house six days to keep a minimum of 50° in the winter.

For anything over a minimum of 50° gas is usually too costly a fuel, and in this case it is advisable to heat the house on the tank system, with a coke boiler, the little extra trouble being fully compensated for by the saving in cost."

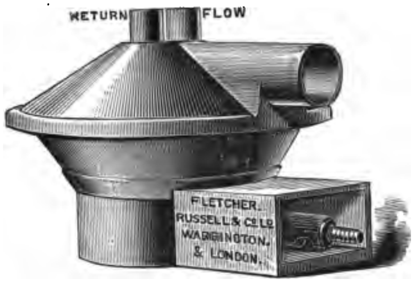


Fig. 50.
FLETCHER'S WEBBED BOILER.

INSTRUCTIONS FOR GREENHOUSE (GAS) BOILERS.

"**The following instructions** are necessary for all (gas) circulating boilers, and must be strictly followed if failures and waste are to be avoided:—

A flue is necessary to carry the products of combustion away; they are damp and disagreeable in a room, and are injurious to plants.

For greenhouses, the flue must have a dip in the lowest part to collect the condensed products of combustion, with an outlet pipe about ¼ inch diameter to drain away the condensed water and prevent it returning to the boiler. If the condensed products of combustion are not removed in this way they will rust the pipe and boiler away. The heat from the flue is equal to about 10 feet of 4-inch pipes, and therefore its use is a decided economy.

A damper should be put in the flue to prevent excessive draught and waste of heat, and the heat of the flue should be utilized as much as possible if for greenhouse use, by taking the flue 6 or 8 feet horizontally in the house, and returning it again to an outlet over the boiler lighting hole.

For domestic use the flue must not go simply through a wall to the outside, or it is almost certain to fail. It must go either into a false roof or into a chimney, and must be quite safe against down-draught, which will instantly extinguish any burner."

"In setting for a greenhouse the lighting hole must be outside, through a wall, and must have no communication with the plant space. The end of the flue must be exposed in the same way exactly as the lighting hole, and must face in the same direction—not upright—so that all winds act equally on both openings. If the lighting hole is in a shed or room the flue must end also in the same room, or the draught will be unreliable in windy weather. If the openings are outside and in a draughty corner, so that the winds are liable to act unequally on them, both openings should be protected by a single box or casing, freely perforated from top to bottom on one side only. The flue must be large enough in diameter to fit outside the nozzle on top of boiler.

One or more boilers can be placed on the same pipes and in the same circuit as a fire boiler, so that either or both can be used.

The burner must be occasionally examined and kept clean.

In severe weather about one cubic foot of gas per hour is required for every 1½ to 2 square feet of hot water pipe surface.

The boiler may get dirty inside with sulphurous deposit; a bucketful of hot water poured sharply down the flue will clear this out. This should be done at least once every year."

CHAPTER XI.

CHIMNEYS, FIRE BARS, FLUES & FUEL.

For steam boilers, where a keen or rapid draught is required, it is necessary to have lofty chimneys, but for hot-water boilers they are not often available, low chimneys being generally sufficient.

The area of the chimney is very important (see Table 9), if too small the draught will be sluggish, and the flues will rapidly choke with soot. Horizontal flues should not be less than one-fourth and vertical one-fifth the area of the fire-bars.

Iron pipes are frequently used for the chimneys of small independent boilers, and if too small they will choke up in three or four days. They should not be less than 4½ inches diameter for the smallest boiler. Brick chimneys are best where available. For large boilers, where the flues travel three, four, or five times the length of the boiler, the chimney must be carried higher in proportion to the draught required.

Where practicable the height of chimney should be 25 per cent. to 50 per cent. greater than the total length of horizontal flues, *i.e.*, a boiler 8ft. long, with flue travelling twice its length, should be 20 to 24ft. high, but if the flues travel three times the length, then 30ft. to 36ft. high would be a better proportion. The total length (horizontal) of flues should not in any case exceed the height of chimney.

FIRE-BARS.

The various parts of an apparatus should all bear some relative proportion one to another. How often is it the case that a haphazard or "rule of thumb" practice prevails, *i,e.*, without system, rule or method. As the consumption of fuel (which is a perpetual item of cost) depends in some measure on the area of the fire-bars, it is of no slight importance that these should be properly proportioned. It does not follow that by reducing the area of the bars you ensure economy, for, if the area is too small, forced draught and frequent attention would be necessary to get the required amount of work out of the boiler. I have known instances where, by increasing the area of bars, corresponding decrease in fuel and saving in expense have been the result. The relative proportions given in Table 9 are compiled after eighteen years of constant daily experience, and will, I believe, be found useful and reliable:—

TABLE 9.

Area of **Fire-bars,** and **area** of **Chimneys.**

For	Fire-bar Area Sq. inches.	Chimney Area Sq. Inches.	
Plain Saddle Boilers allow	50	12	For each **100 feet super** of pipes or radiator surface.
Check End Saddle Boilers allow	45	12	
Chambered (one flue) Saddle Boilers allow	40	12	
Chambered (two flues) Saddle Boilers allow	35	12	
Trentham Saddle Boilers allow ...	35	12	
Excelsior Saddle Boilers allow ...	35	12	
Titan (or similar with straight draught)	30	10	

Note.—The fire-bar area includes bars and spaces between them.

The area of bars in Keith's Sectional Challenge Boilers varies from 14 to 28 square inches for every 100 feet heating-power. In these boilers coke is used for fuel; they have also a straight vertical draught, and a very large heating surface directly exposed to the flame impact, otherwise the fire-bar surface would be insufficient for effectively heating the quantity of pipes.

The following rules and examples are given for ascertaining the velocity of air currents either in chimneys or ventilating flues.

Rule 1.—To ascertain the **velocity** of draught in feet per second.

The Square Root of difference in degrees temperature, × height of flue (in feet) × ·09 = Velocity (in feet) per second.

Example 1.—Required velocity of air in ventilating flue 20ft. high, when the difference between inside and outside temperature is 25°.

Diff. in
25° the square root = 5 × 20 × ·09 = 9ft. per second velocity.

Example 2.—Required velocity of draught in chimney 80ft. high, with difference in temperature of 100°.

Diff. in temp.
100° the square root = 10 × 80 × ·09 = 72ft. per second velocity.

Rule 2.—To ascertain the **difference** in **temperature** when the velocity is known.

Velocity (in feet) ÷ ·09 ÷ height of chimney (in feet), then square the product.

velocity.
Example 3.— 9ft. ÷ ·09 ÷ 20 = 5 then 5 × 5 = 25° difference in tem.
" 4.—72ft. ÷ ·09 ÷ 80 = 10 then 10 × 10 = 100° " "

Rule 3.—To ascertain the **Cubic feet** of air discharged per second.

Velocity (in feet) per second × area of flue (in feet) = Cubic feet of air discharged.

Example 5.—With velocity in flue of 4 feet per second and area ·5ft., how many cubic feet are discharged?

velocity
4ft. × ·5 = 2 cubic feet per second.

Example 6.—With velocity in chimney of 60ft. per second and area of 4ft., how many cubic feet are discharged?

velocity
60ft. × 4 = 240 cubic feet per second.

Rule 4.—To ascertain the **Area** of **Flue** from the amount and velocity of discharge.

Cubic feet of air discharged per second ÷ Velocity in feet per second = area of flue.

Example 7.—With 240 cubic feet discharged per second, and velocity of 60ft. per second, what is the area of flue?

cub. ft.
240 ÷ 60 = 4ft. super. area of flue.

FLUES.

Flues are very liable to get foul from accumulations of soot, especially when small or contracted. For small saddles with approximate heating power, say up to 500 feet, the flue round the boiler should not be less than three inches, from 500 to 1,000 feet 3½ inches to 4 inches, and for larger sizes 4½ inches to 5 inches. Sometimes boilers are set with a (winding draught) single flue, sometimes it is divided into two flues (split draught). Whether there be one or more flues, the combined area should be equal to the area of the chimney; if contracted in any part it is liable to affect the draught or to get choked with soot.

FUEL.

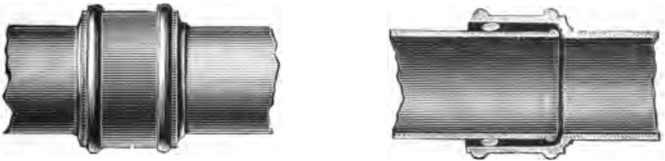
For most wrought boilers coal or rough slack is suitable; sometimes a mixture of coke will give better results and cause less soot or deposit. For tubular boilers, either cast or wrought, whether the flame acts externally or passes through the tubes, coke or anthracite coal is the best, as they soon get choked with soot if slack or ordinary house coal is used. Coke or embers from the house fire are the best fuel for small independent boilers. For banking up at night, coke is not so suitable, it clogs and sticks, especially in small boilers, leaving portions of the fuel unconsumed, the fire out, and the pipes cold; with rough slack the fire will last longer, a feature of the utmost importance with small boilers.

CHAPTER XII.

JOINTS.

In the old-fashioned system of jointing, commonly known as socket and spigot pipes, the joints are made in various ways. Sometimes two or three coils of rope yarn are first placed in the socket and driven in with a caulking tool, and the rest of the socket filled in with cast-iron borings that have been moistened with vinegar, or with water in which a little sal-ammoniac has been dissolved to make them rust quickly. These borings set as hard as the iron itself, but if an undue quantity is put in, or if caulked too hard in the socket, it will, on the expansion of the metal, cause the socket to crack and leak. A better method is to put alternate layers of red or white lead between the coils of the rope yarn, filling in about half an inch of the socket with cast borings to finish with. This will make, when set, a strong and firm joint.

There are several kinds of cement now used for this purpose instead of red lead. The following is a good recipe, and is cheaper and cleaner to use than white lead:—One part of litharge and two parts of chalk to three parts silver sand, mixed with boiled linseed oil to the consistency of stiff putty; caulk in with the yarn as before described.



SOCKET JOINT SECTION OF JOINT

Fig. 51.

SOCKET-JOINT AND SECTION.

Socket-joints are frequently made with a rubber ring, round in section, which is placed on the spigot end and rolled into the socket, see Fig. 51; sometimes the socket is filled in with cement or borings to make the joint firmer, and to insure it against leakage. If the sockets and pipes are uniform, and the rubber of good quality and proper size, a fairly good joint is made without any addition of cement, &c.

There are other methods, such as with molten lead, &c., but one of the many objections to socket-joints is that if you require to make alterations or connections after they are fixed, the pipes must be cut or broken, or if in the middle of a range you must commence at one end and disconnect several joints before you can get at the one required. Another objection is the length of time it takes to make, and the increased length of time to take it to pieces; if a joint leaks it is frequently more trouble to stop the leakage than to make the joint in the first instance.

The flange joint, *i.e.*, a pipe cast with a flange on each end, is usually made with a flat rubber ring and screwed together with two, three, or four bolts and nuts. It makes a strong joint, but is not very neat in appearance. These joints are not much used for horticultural work, as they are more expensive, and serious delays are occasioned in waiting for special lengths, as they cannot be shortened or lengthened, but must be cast to the dead length required.

There are also special joints, such as Truss's patent and Haden's patent. The former consists of a ring about two inches broad, cast in three sections, and two lugs on each section for bolts; the sections have grooves inside, and the ends of the pipes have beads to correspond with the grooves; a rubber band, about 2 inches broad by $\frac{3}{8}$ inch thick, is placed on the ends of the pipes, and the sections or clips are then secured on the rubber with the three bolts and nuts. As the pipes have special ends, and for making up need to be cast to special lengths required, the same objection applies to them as to the flanged pipes. In screwing up the joint the rubber band is liable to pucker and leak between the clips—a very objectionable feature.

Haden's patent is better in principle than Truss's, and consists of socket and spigot ends. The socket has two lugs for the bolts, and has two recesses; a rubber ring, placed on the spigot end of the pipe, is screwed, by means of a loose flange, against the first shoulder of recess, and the spigot end of the pipe goes into the second and smaller recess. These joints have some good features, but are open to several of the objections already alluded to.

A joint of more recent invention, and which has several points of excellence, is the expansion joint. This joint, (invented by the writer, in 1874), consists of two loose flanges and one iron ring, and is made by compressing with two bolts and nuts, two rubber rings between the ends of the ring and the shoulder inside the flange, thus binding the rubber rings firmly round the pipes about one inch from the end of each.

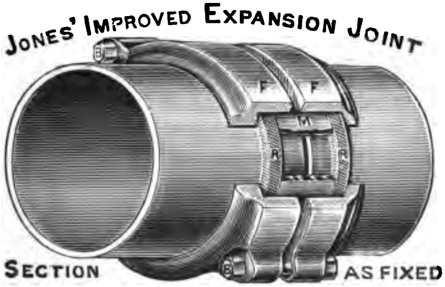


Fig. 52.

These Joints have been extensively used for 19 years, during which time the demand has steadily increased:

they may be safely used with 100 ft. head of **cold** water but they are not suitable for more than **25** to **30 ft.** head of **hot** water. For any height below this they possess advantages over all other joints in use. They are moderate in price, quickly made, not liable to fracture from expansion or contraction, they may be fixed by inexperienced persons, and alterations or additions can be made in one-fourth the time that would be required with most other systems of jointing, and in case the water in the pipes should be frozen, the joint is forced off by the expansion, and frequently without damage to pipes, joints, or connections. During the frost of January, 1893, the water in about 1,400 ft. run of 4-inch pipes at some Board Schools was frozen solid throughout. Every pipe had to be disconnected, taken outside, thawed, and refixed, there were only about 8 or 10 lengths damaged; whilst in another block of School Buildings where socket pipes were used, there was scarcely a sound pipe or connection left, and new ones had to be substituted throughout. I have known scores of cases with results similar to those here described.

There are many other joints in use, some of which have been patented, but space will not permit a full description of them.

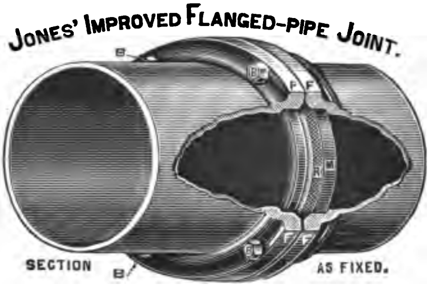


Fig. 53.

Fig. 53 is an illustration of a new flanged joint (invented by the writer) that is specially suited for lofty buildings, and one that may be safely used with **hot** or **cold** water up to **100 ft.** head.

Its special features are; the ends of the pipes and connections are all alike, the flanges FF are round, small in diameter, and cast on solid, four bolts and nuts BB are used at each joint. There are no lugs for bolts, no sockets or spigots, no male or female ends, no right or left hand castings; all are interchangeable.

The middle ring M fits into recesses in the ends of the pipes, the rubber ring R is compressed between the bevelled faces of the flanges, thus making a perfect joint which possesses a certain amount of elasticity. Having 4 bolts the strain is equalized, and when fixed they have a very neat appearance.

For cut lengths or final joints, malleable flanges are supplied which may be sunk on hot, or fastened on cold with a small punch, thus avoiding the delay of waiting for special lengths.

* * *

CHAPTER XIII.

MAIN PIPES.

The relative diameters of Mains should be carefully considered, when planning or setting out an apparatus, first ascertain the total amount of radiating surface that is likely to be put upon the boiler, next the probable levels at which these are to be fixed; the flow pipes should have an upward pitch or rise, and the return pipes a fall, of say 1 inch in 30 ft.

Increased velocity means greater power to overcome obstacles, therefore select pipes and connections with smooth internal surfaces, avoid square elbows, tees, or other connections that have branches at right angles with sharp edges and contracted passages, these increase the friction, retard the circulation, and reduce the efficiency of the apparatus. The friction in vertical pipes is slight, hence the risers to upper floors may be smaller in diameter than horizontal pipes; the diameter of all pipes should have some relative proportion to the amount of radiating surface they have to supply.

TABLE 10.

Approximate sizes of mains for various quantities of pipes or radiators.

Total radiating surface not exceeding	Horizontal Mains. Internal diameter.	Vertical pipes or risers.
100 ft. super.	1¼ inches	1 inch
250 ,, ,,	1½ ,,	1¼ ,,
600 ,, ,,	2 ,,	1½ ,,
800 ,, ,,	2½ ,,	2 ,,
1,000 ,, ,,	3 ,,	2 ,,
1,500 ,, ,,	4 ,,	2½ ,,
2,500 ,, ,,	4 ,,	3 ,,
4,500 ,, ,,	5 ,,	4 ,,
6,000 ,, ,,	6 ,,	5 ,,
8,000 ,, ,,	7 ,,	6 ,,
10,000 ,, ,,	8 ,,	6 ,,

For any other quantity of radiating surface, the dia. of horizontal main pipes may be found as follows:—

Ft. Super of Radiating Surface ÷ 200 = Area (in square inches) of main pipe.

If the area does not correspond with any commercial size, adopt the next size above.

Example.—For 2,000 ft. super ÷ 200 = 10 in. the area of pipe required; a 3 in. pipe having an area of 7 in. is too small, adopt a four inch instead, which has 12·56 sqr. in. area.*

Mr. W. J. Baldwin in his excellent book on "Hot Water Heating" gives diagrams and tables with Mains much larger than those here given; they are based on a loss of temperature of 10° and 15° between the flow and return pipes. The diagram he gives shows a 7-inch main for a 300 ft. circuit of pipes having 1,600 ft. of radiating surface. There are numerous instances where a 4-inch main supplies from two to three times this quantity with satisfactory results. The temperature is reduced more than 10°, but when all the pipes are inside the building, the slight increase in efficiency with a 7-inch instead of a 4-inch main would scarcely be appreciable, and would not in my opinion compensate for the heavy outlay involved by the increased size of mains. Another important advantage is that a 4-inch occupies less space, and is neater in appearance than a 7-inch pipe.

When 2 or more main flows are taken off the boiler, the area of each should be proportioned to the amount of radiating surface it supplies.

It is a good practice to reduce the verticals or risers leading to the upper floors of lofty buildings, and to proportion the area of each riser accordingly.

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*See Area of Pipes, Table 12.

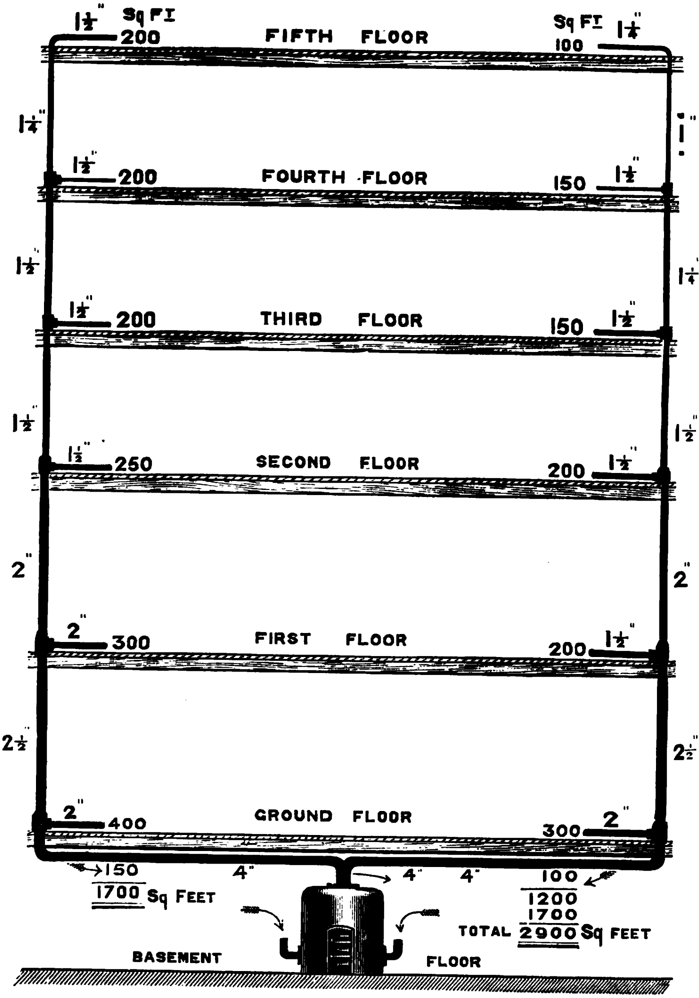
1½" Sq FT 200
FIFTH FLOOR
Sq FT 100 1¼"
1¼"
1"
1½" 200
FOURTH FLOOR
150 1½"
1½"
1¼"
1½" 200
THIRD FLOOR
150 1½"
1½"
1½"
1½" 250
SECOND FLOOR
200 1½"
2"
2"
2" 300
FIRST FLOOR
200 1½"
2½"
2½"
2" 400
GROUND FLOOR
300 2"
150
1700 Sq FEET
4"
4"
4"
100
1200
1700
TOTAL 2900 Sq FEET
BASEMENT
FLOOR

Fig. 54.

Fig. 54 illustrates the method of heating the floors of a lofty building to obtain as nearly as possible uniform temperatures in all the pipes and radiators on the various levels, the total surface of pipes, &c., is assumed to be 2,900 square feet, one rising main supplies 1,700, and another 1,200 feet, the superficial feet supplied by each main, on each floor, with the diameters of horizontals and verticals are all clearly marked, and are calculated on the basis given in Table 10.

When a number of branches are taken from one main, the water will sometimes rush along one branch and create a short circuit, *i.e.*, the hot water will get round one circulation more quickly into the return pipe, and thus prevent the others from getting hot; this may be caused, first, by one range of pipes being on a higher level, second, by one horizontal main being shorter than another, and third, by a branch taken off the *top* of the horizontal main near boiler. It may be prevented, first, by reducing the inside diameter of riser with a bushing or disc, second, by reducing the horizontal main, and third, by taking the branch off the *side*, instead of the *top* of the main flow pipe.

Valves should be fixed on all branches, and especially when on various levels, and then all circuits may be easily regulated, but a properly designed apparatus, with all the parts properly proportioned, the circulation should be nearly equal when the valves are all opened irrespective of levels or length of circuits.

A good deal of waste is often occasioned by the disproportionate length of mains that are unavailable for heating, or by their exposure to the atmosphere. The following will show the importance of taking these matters into consideration when setting out new work:—

Being requested to examine and report upon the merits of an apparatus used for heating the horticultural buildings of the Right Hon. Earl of S———, and to suggest some means for economizing the fuel, the following is a brief summary of the state of things as they existed, and will give some idea of the enormous waste constantly going on :—

There were in all thirty ranges of horticultural buildings. The stove-houses which required constant heat and the highest temperatures, were fixed some distance from the boilers instead of being placed as near as possible.

There were two "Trentham" boilers, 12 feet long by 4 feet diameter, with 6-inch water-space, and 5 Galloway tubes in each boiler.

Length of radiating-pipes in houses (equivalent to 4-inch) to 10,670 feet; length of mains, unavailable for heating (equivalent in 4-inch) to 2,700 feet. Giving a length of pipes of about 25 per cent. practically wasted.

The mains were 4, 5, 6, and 8-inch pipes, thus holding a large quantity of water.

Water contained in—		Gallons
Radiating-pipes	about	4,700
Main-pipes	„	1,470*
Boilers	„	840
Total ...		7,100

*Equals 30 per cent. waste.

The length of mains and the quantity of water were altogether disproportionate to the radiating pipes; the mains were mostly in large brick channels, and were not covered with non-conducting material.

The loss of heat from exposed pipes is considerable, as will be seen from the examples quoted below. I tried several experiments to test the relative value of non-conducting materials, and give the results of two of them :—

Experiment 1.—I took two 4-inch pipes, 2 feet long each. One was encased with sheet-iron 24-gauge, which was 2 inches larger in diameter, thus leaving a 1-inch air-space all round the pipe; this space was first filled with loose silicate cotton, and afterwards with sawdust. The other pipe was left exposed to the air, without any covering. Both pipes were filled with water, 1 Gallon in each, at 162° Fahr., the ends sealed, and then exposed to the outer air, which was 33 degrees.

		h. m.		Average time for each Deg. m. s.
The pipe encased with silicate cotton cooled	90° in	9 45	=	6 28
„ „ sawdust cooled	90° in	8 4	=	5 22⅔
The pipe uncovered, exposed direct to the air cooled	90° in	2 30	=	1 40

The uncovered pipe cooled 3·88, or nearly four times as rapidly as the one encased with silicate cotton. The waste from this source will be manifest.

Experiment 2.—A Fahrenheit thermometer was laid on the top of a steam-heated coil and covered with a sheet of hair-felt. In a short time the thermometer registered 206°. Next, a wood skeleton frame 1½-inch thick, the inside edges of the frame being rabbetted, and a sheet of 24-gauge sheet-iron placed in each rabbet, leaving an air-space of 1½-inch between the sheets; the edges of the plates were made air-tight with putty. The one sheet was in contact with the steam coil, and the thermometer placed on the other, and in 3 hours the thermometer registered 82 degs. The space between the sheets was then filled with various materials, the time and temperatures respectively registered being as under :—

FRAME FILLED WITH	Left for	Highest Temp. Registered.
Leroy's boiler-covering composition ...	3 hours	94°
Asbetos powder	4 „	86°
Hair felt	9 „	77°
Silicate cotton	9 „	76°

I know of no substance that is, in the strict interpretation, a ***non-conductor***, but, taken in the generally accepted sense of the term, silicate cotton is the best I have tried, and will, if properly applied, prevent a good deal of the loss of heat by radiation, as shown by the above tests. I cannot enter fully into the many and various suggestions embodied in the report referred to, but I have no hesitation in stating that a wise forethought in planning out the work would have effected a saving of at least 50 per cent. in fuel, the cost of which including six miles haulage from the station, represented an important item in twelve months.

Similar instances, though on a smaller scale, are to be met with very frequently. The probabilities and possibilities of future extensions should be well considered, and the perpetual cost of wear and tear, fuel consumption, &c., should receive special care and consideration.

The following table of the comparative values of the various substances for boiler or pipe coverings, as published in a recent number of "Engineering," practically confirms my own tests as given above.

TABLE 11.

NON-CONDUCTING BOILER OR PIPE COVERINGS.

Prepared Mixtures for covering Boilers, Pipes, &c.	Pounds of water heated 10° Faht. per hour, per square foot.
Slag wool (silicate cotton) and hair paste	10·0 lbs.
Fossil meal and hair paste	10·4 ,,
Paper pulp alone	14·7 ,,
Asbestos fibre wrapped tightly	17·9 ,,
Fossil meal and asbestos powder	26·3 ,,
Coal ashes, and clay paste wrapped with straw ...	29·9 ,,
Clay, dung, and vegetable fibre paste	39·6 ,,
Paper pulp, clay and vegetable fibre	44·6 ,,

Slag wool, and Fossil meal are the best, both are readily applied, and are practically indistructible.

CHAPTER XIV.

PIPES, QUANTITY, SIZE, AND VALUE OF.

The quantity of pipes required to perform certain work being under-estimated, is a frequent cause of failure. It is essential that the amount of piping should be calculated according to the cubical capacity of the building and the temperature required. The quantity of air to be warmed per minute is 4 cubic feet for each person, adding 1¼ cubic feet for each square foot of glass in habitable rooms or public buildings. For horticultural buildings the quantity of air to be warmed is 1¼ cubic feet per square foot of glass per minute. Iron frames and sashes are measured with the glass; for wood frames deduct one-eighth from the gross area of surface.

To find the length in feet of iron pipes required for heating the air in a building, Hood gives the following

RULE:—

"Multiply the volume of air in cubic feet to be warmed per minute by the difference in maximum temperature of the room and the external temperature; and multiply by 1·12 for 2-inch pipes, by ·75 for 3-inch, and ·56 for 4-inch pipes, and divide the product by the difference of the internal temperature and that of the pipes.

There are several objections to this rule.

1. It would generally be difficult, and often impossible, to obtain the necessary information upon which to base the calculation.

2. The cubical contents are left out of the calculation.

3. It is a circuitous method of obtaining the lengths required.

4. The results when they are obtained are unreliable.

As the rule was first published by Hood, and has been freely copied in a number of other works, it may be considered impertinent to question its veracity. I have frequently put it to the test for churches, schools, and various other buildings, and have in all cases found the discrepancies such as would not justify its adoption. I give below one or two instances in confirmation of this statement:—

The first was a church with lofty interior, and the window-surface of which was small in comparison to the cubical contents of the building, the following are the particulars:—

Internal capacity of church	176,000 cubic feet.
Area of glass in windows	688 square feet.
Total seating accommodation	800 persons.
Average attendance	400 persons.

Now, if we base our calculations on the cubic capacity, and allow 10 feet run of 3-inch pipes per 1,000 cubic feet, which in practice will give a temperature of about 25° above the outside temperature, or, say 55° inside when 30° outside, it would give 176 x 10 = 1,760 feet of 3-inch pipes, and tested by Hood's rule, which is quoted above, the results are as follows:—

Window surface, 688 feet × 1¼
(allowance for glass) = 860 .. ..
Number of persons, 800 × by 4 (allowance for each person) = 3,200 ..
= 4,060 feet of air to be warmed per minute.

Take the required temperature .. .. .. 55°
And external temperature .. . . 30°

Gives . .. . 25° difference.
Suppose the temperature of pipes to be .. .. 190°
Suppose the temperature of room to be .. .. 55°

Gives .. .. 135° difference.

4,060 × 25 × ·75 = 76,125 ÷ 135 = 563 feet of 3-inch, *i.e.*, about one-third the quantity actually required.

If the allowance of air is calculated for 400 persons (the average attendance) instead of 800 (the total seating accommodation), the result is 341 feet of 3-inch pipes, about one-fifth the quantity actually required.

The above is one instance taken from everyday experience the dimensions being carefully taken, and the seating accommodation procured with a view of obtaining some data that may be reliable.

The following is a case in which we will suppose a

Room 10 feet × 10 feet × 10 feet = 1,000 cubic feet
One window 6 feet × 4 feet = 24 square feet
Number of Persons 4
Then—Window surface 24 × 1¼ = 30 (allowance for glass)
Number of persons 4 × 4 = 16
Total... ... ... 46 feet of air to be warmed per minute.
46 × 25 × ·75 ÷ 135 = 6 feet of 3-inch pipes.

Now, suppose the size of room to be increased, say—

Room 40 feet × 20 feet × 20 feet = 16,000 cubic feet
Four windows 6 feet × 4 feet each = 96 square feet
Number of persons, say 40
Then—Window surface 96 × 1¼ = 120
Number of persons 40 × 4 = 160
Total ... ... 280 feet of air to be warmed per minute.
280 × 25 × ·75 ÷ 135 = 38 feet of 3-inch pipes.

Although the cubic capacity is increased sixteen times, the length of pipes is only increased about six and a half times. These examples will show that the basis of calculation is defective, and the rule for practical purposes altogether unreliable.

TABLE 12 is taken from Hood's book, his calculations are based on a water temperature of 200° Fahr., and as the temperature in actual practice is usually much lower than this, the length of pipes should be correspondingly increased. For public, private, or horticultural buildings, where moderate temperatures are required, say, 50° to 70°, it is a decided advantage to obtain these temperatures with an increased length of pipes moderately heated. The first cost will be somewhat higher, but the compensating advantages of a mild, pleasant, humid, and agreeable temperature will repay for the slight additional cost.

TABLE 12.

Length of 4-inch Pipe *to Heat* 1,000 *Cubic feet of Air per Minute : Temperature of the pipe* 200 *deg. Fahr.* (HOOD).

Temperature of External Air. Fahrenheit's Scale.	TEMPERATURE AT WHICH THE ROOM IS REQUIRED TO BE KEPT.									
	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
10°	126	150	174	200	229	259	292	328	367	409
12°	119	142	166	192	220	251	283	318	357	399
14°	112	135	159	184	212	242	274	309	347	388
16°	105	127	151	176	204	233	265	300	337	378
18°	98	120	143	168	195	225	256	290	328	368
20°	91	112	135	160	187	216	247	281	318	358
22°	83	105	128	152	179	207	238	271	308	347
24°	76	97	120	144	170	199	229	262	298	337
26°	69	90	112	136	162	190	220	253	288	327
28°	61	82	104	128	154	181	211	243	279	317
30°	54	75	97	120	145	173	202	234	269	307
*32°	47	67	89	112	137	164	193	225	259	296
34°	40	60	81	104	129	155	184	215	249	286
36°	32	52	73	96	120	147	175	206	239	276
38°	25	45	66	88	112	138	166	196	230	266
40°	18	37	58	80	104	129	157	187	220	255
42°	10	30	50	72	95	121	148	178	210	245
44°	3	22	42	64	87	112	139	168	200	235
46°	—	15	34	56	79	103	130	159	190	225
48°	—	7	27	48	70	95	121	150	181	214
50°	—	—	19	40	62	86	112	140	171	204
52°	—	—	11	32	54	77	103	131	161	194

* Freezing point.

For rapid calculations the following table will be found most useful, bearing in mind that all tables must be considered as approximate only. The position and aspect of the building should be considered; if it is in an exposed position, or has a north, or north-east aspect, or if it has a number of corners or angles, an increased length of pipes will be required. When placed in channels or trenches, from 15 to 25 per cent. extra piping should be put in to allow for the absorbtion of heat by the soil and brickwork.

For stoves, drying-closets, &c., where a temperature of 90 deg. to 120 deg. is required, the water must be kept nearly boiling to maintain the required temperature.

*TABLE 13.

Length of **4-inch** pipe, or **feet superficial** required for every **1,000 cubic feet,** when the outside temperature is 30° and the **mean** temperature of water in flow and return pipes is 160° to 170° Fahr.

DESCRIPTION OF BUILDING.	Temp. Reqd. Fahr.	Per 1,000 cub. ft. **4-inch pipes.**	**feet sup.**
Factories where muscular exercise is required	50°	6 feet	7½
Store rooms, Warehouses, Coach-houses, &c.	55	8 ,,	10
Churches, Schools, Public Buildings, &c. ...	60	11 ,,	13
Shops, Living Rooms, Hospitals, &c. ...	65	15 ,,	17
Hospitals, Operating Rooms, Entrance Halls,	70	20 ,,	23
Varnishing Rooms for Carriage Builders, or for drying any class of goods at moderate temperatures in rooms with windows in	75	27 ,,	31
	80	36 ,,	42
	85	49 ,,	56
	90	65 ,,	75
Drying Stoves for Bacon, Cloth, Wool, Timber, Leather, Skins, Paper, Laundry, or other purposes (without windows), and with moderate ventilation	95	82 ,,	95
	100	97 ,,	112
	105	115 ,,	132
	110	135 ,,	155
	115	158 ,,	182
	120	186 ,,	214
	125	220 ,,	252
	130	260 ,,	300

For temperatures over 130°, steam or high-pressure hot-water are more suitable than low pressure.

NOTE.—**A laundry** or other drying-stove giving 120° to 130° when goods are dry, will register only 90° to 100° whilst they are saturated with moisture.

HORTICULTURAL.			
Cool Houses to keep out frost ...	40° to 45°	37 ,,	42
Conservatories, Peaches, &c. ...	45 to 50	40 ,,	46
Greenhouses, Ferneries, &c.... ...	50 to 55	44 ,,	50
Vines, Strawberries, Tomatoes, &c. ...	55 to 60	49 ,,	56
,, ,, ,, ...	60 to 65	54 ,,	62
Pits, Melons, Cucumbers, &c. ...	65 to 70	59 ,,	68
Tropical Plants, Stoves, Orchids, &c. ...	70 to 75	65 ,,	75
Pines, Propagating, Forcing, &c. ...	75 to 80	72 ,,	83
,, ,, ,, ..	80 to 85	80 ,,	92

For bottom heat for cucumbers, pines, &c., the following is about a fair proportion :—

For bed 2 feet wide	Two 3-inch pipes.
For bed 3 feet wide	Two 4-inch pipes.
For bed 4 feet wide	Three 4-inch pipes.
For bed 5 feet wide	Four 4-inch pipes.

The surface of pipes used for bottom heat should not be reckoned for radiating purposes, as the heat is mostly absorbed before it finds its way into the house.

*This table has been specially prepared by the Author, after several weeks of careful experimental tests, and is Entered at Sationers' Hall.

TABLE 14.

Area of Pipes, *with quantity of Water (in Gallons) and Weight (in Lbs.) for each Foot in Length.*

Inside Diameter Inches.	Area in Inches.	Gallons per Foot Run.	Weight of Water in Lbs. per Foot Run.
½	·19635	·0085	·085
¾	·44178	·0192	·192
⅞	·60132	·0260	·260
1	·7854	·0340	·340
1¼	1·227	·0531	·531
1½	1·767	·0764	·764
1¾	2·405	·1041	1·041
2	3·142	·1360	1·360
2½	4·908	·2124	2·124
3	7·069	·306	3·06
4	12·566	·544	5·44
5	19·635	·850	8·50
6	28·274	1·224	12·24
7	38·484	1·666	16·66
8	50·265	2·176	21·76
9	63·617	2·754	27·54
10	78·540	3·400	34·00
11	95·033	4·114	41·14
12	113·097	4·896	48·96
13	132·732	5·746	57·46
14	153·938	6·664	66·64
15	176·715	7·650	76·50
16	201·062	8·704	87·04
17	226·980	9·826	98·26
18	254·469	11·016	110·16
19	283·529	12·274	122·74
20	314·160	13·600	136·00
21	346·361	14·994	149·94
22	380·133	16·456	164·56
23	415·476	17·986	179·86
24	452·390	19·584	195·84

Remove the decimal point (in gallons per foot) two places to the right will give the number of gallons in 100 feet.

Examples.—12-inch pipe = 4·896 gallons per foot, and 489·6 gallons per 100 feet.

The area or contents of any other size may be obtained as follows :—

Diameter of pipe or cylinder squared × ·7854 = the area.
„ „ „ „ × ·034 = gallons per ft. run
Area of pipe or cylinder in inches ÷ 23·1 = gallons per ft. run
Gallons of water (any number of) × 10 = weight in lbs.

Now although Table 13 is very useful, the data being generally obtainable, and the calculations easy, it is not absolutely reliable; in rooms or buildings which have a small cubic capacity, and a large surface of glass, the amount of piping will be insufficient, whilst in places with a large cubic capacity and small glass surface the amount of piping will be more than enough. Some tables base the amount of heating surface on the superficial surface of glass only, irrespective of the cubic capacity, and the heating surface thus arrived at appears to be excessive for small greenhouses and insufficient for those with a large cubic capacity.

I have an American catalogue which contains some elaborate tables and calculations based on the data given by Baldwin; the (exposed) wall surface, the window surface, the cubic contents, and the cubic feet of air to be warmed are all given in detail, the calculations must have involved an immense amount of trouble, yet one table shows 14 feet superficial per 1,000 cubic feet for one room, and 44 feet per 1,000 for another, to attain in both instances 70° temperature inside when zero outside. A second table shows 22 feet superficial per 1,000 for one room and 60 feet for another, while a conservatory has only 64 feet per 1,000 to give a similar temperature of 70° above the outside temperature, other tables have discrepancies of a similar nature, hence the data or basis of calculation must be at fault somewhere.

Now, a rule to be appreciated by the trade generally must be simple, the data easily obtainable, and should apply to buildings varying in size and construction, and after many tests and experiments I believe Rule 15 will meet these requirements. I have applied it to a number of churches, schools, dwelling rooms, greenhouses, and other buildings and believe that it is a nearer approach to accuracy than any rule hitherto published. The allowance made for cubic capacity is intended to warm the air in the room and also to overcome the cooling effect of walls, etc., the additionals are to counteract the cooling effect of the glass whatever the extent of its surface.

*RULE **15**, by the Author.

To obtain **60° inside** when **30° outside** in ordinary rooms or in greenhouses.

Allow 1 foot superficial of heating surface per 100 cubic feet capacity.
Add 1 foot superficial of heating surface per 6 square feet of glass; or
Cubic feet capacity ÷ 100 + feet superficial of glass ÷ 6 =
Heating surface (feet superficial) required.

If the room has four sides exposed, or has thin walls, or exposed angles with north or east aspect, some allowance may be necessary, and this would apply whatever rule is adopted.

RELATIVE VALUE OF PIPES OF DIFFERENT SIZES.

In Hood's book the length of 4-in. pipes required for 1,000 cubic feet capacity is given, and it says:—"For 3-in. pipes add one third to the quantity, and for 2-in. add double the quantity"—and this would be correct if it referred to the outside diameters of the pipes, because the heating surface is determined by that portion of the pipe with which the air comes in contact, i.e., the external surface: but as the dimensions given for hot water, cold water, or steam pipes invariably refer to the inside diameters, the statement is somewhat misleading, as will be seen by the following.

Assuming the **inside** diameters are 2-in. 3-in. and 4-in. and metal $\frac{1}{4}$-in. thick, the **outside** diameters would be 2·5, 3·5, and 4·5 in.

Now, although the inside diameter of 4 is double that of 2, the outside diameters (and the circumference also which bears the same ratio to the diameter) of 4·5 is not double that of 2·5.

*Copyright.

Let us take 2 examples, the length and diameter of one size being given to find its equivalent in any other size.

Rule.—Length of pipes × outside diameter (or circumference) ÷ outside diameter (or circumference) of the required size.

Example 1.—If 500 ft. of 4-in pipes are required, what length of 2-in. will give equal results. $\frac{500 \times 4}{2} = 1000$ ft. of 2-in.

but if 500 ft. of 4·5-in. pipes are required, what length of 2·5-in. will give equal results $\frac{500 \times 4{\cdot}5}{2{\cdot}5} = 900$ ft. of 2in. or a difference of 10 $^{0}/_{0}$

Example 2.—If 1000 ft. of 2-in. pipes are required what length of 6-in. will give equal results $\frac{1000 \times 2}{6} = 333$ ft. of 6-in.

but if 1000 ft. of 2·5-in. pipes are required what length of 6·5-in. will give equal results $\frac{1000 \times 2{\cdot}5}{6{\cdot}5} = 384$ ft. of 6-in. or a difference of 15 $^{0}/_{0}$

From these examples it will be evident that the **external** surface and not the **inside** diameter, should form the basis of calculation. It should be here stated that although the **heating surface** of a 4-in. pipe is about double that of a 2-in. the **quantity of water** contained in a 4-in. is four times that of a 2-in. the relative proportion of diameter to circumference* (which determines the heating surface) and the proportion of diameter †to area (which gives the capacity) are quite different, and it may therefore be assumed that a boiler would work more efficiently and economically with small, than with large pipes. There is however very little if any practical difference in this respect, as the results depend upon the amount of radiating surface, and the relative power of the boiler, rather than on the quantity of water contained in the pipes.

If an apparatus is required to get up the heat quickly, small pipes or radiators are an advantage, but the heat fluctuates more rapidly, whereas for sustained work, and maintaining steady uniform temperatures, the larger pipes are most suitable.

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* See Table 17, Page 134.

† See Table 14, diameter to area, Page 128.

As heating surface is a term used in various ways, sometimes in feet run of 2, 3, or 4-inch pipes, and at others in superficial feet, the relative value of either may be obtained by the following:—

Rule.—To convert **feet run** into **superficial feet.** Feet run (any number) × circumference of pipe ÷ 12 gives equivalent in feet super.*

Example.—Convert 600 ft run of 2-in. pipes *(circumference 7·854) into superficial feet $\frac{600 \times 7{\cdot}854}{12}$ Answer, 392 feet super.

Rule.—To convert **superficial feet** into **feet run** of any size pipe. Feet superficial (any number) × 12 ÷ circumference of pipe = feet run of pipes.

Example.—Convert 220 superficial feet into feet run of 3-in. pipe *(circumference 11-in.) $\frac{220 \times 12}{11}$ Answer, 240 feet run of 3-in. pipes.

There is a tendency for Manufacturers to reduce the value of pipes by cutting down the sizes, with the object of reducing prices, or making extra profits: take for instance rain water pipes, the diameters of which have been reduced from time to time, one maker following the lead of another until the sizes usually sold are the thickness of the metal under full size, a pipe usually sold for 3-in. is 3-in. from inside to outside, and $2\frac{13}{16}$-in. only inside diameter, and other sizes in like proportion. There are at this time thousands of hot water pipes sold for 4-in. that measure $3\frac{13}{16}$-in. only inside diameter × $4\frac{1}{4}$-in. outside diameter; this is a pernicious system, and cannot be too strongly condemned. When the price of a pipe is lower on account of its smaller diameter, the heating surface is proportionately reduced, besides which it would be a great public convenience if all makers worked to some recognized standard.

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*See also Table 16 and examples page 133.

I have met with 4-in. pipes varying from 4⅛-in. to 4⅞-in. outside diameter, and doubtless other Engineers have had similar experiences: when alterations or additions to existing apparatus are necessary these varying sizes are a great nuisance, often necessitating special patterns thus increasing the cost of repairs, and causing unnecessary delay.

The general adoption of Whitworth's Standard for the sizes of bolts and nuts, and the pitches of thread for the various sizes, and also the uniform pitch of thread on gas and steam tubes, have been a convenience to all Engineers, and the adoption of some such standard for Hot Water and Rain Water pipes is much needed in the interests of all parties concerned.

TABLE 16.

Superficial feet of surface (decimal equivalents) per foot run of tube.

External diameter, inches.	0	⅛	¼	⅜	½	⅝	¾	⅞
0	—	·032	·065	098	·131	·163	·196	·229
1	·261	·294	·327	·360	·392	·425	·458	·491
2	·523	·556	·589	·621	·654	·687	·720	·752
3	·785	·818	·850	·883	·916	·949	·981	1·014
4	1·047	1·080	1·112	1·145	1·178	1·210	1·243	1·276
5	1·309	1·341	1·374	1·407	1·439	1·472	1·505	1·538

Feet superficial (any number of) ÷ by decimal equivalent given in above Table, will give the number of **feet run** in any size required.

Example :—Convert 500 superficial feet into feet run of pipes 4½ inches outside diameter. 500 ÷ 1·178 = 424 feet run.

Feet run (of any given size) × decimal equivalent given in above Table will give equivalent in **feet superficial**.

Example :—Convert 800-feet run of pipes 3¼ inches, outside diameter, into superficial feet. 800 × ·850 = 680 feet superficial.

See also Rules and Examples given on page 132.

TABLE 17.

CIRCLES, DIAMETER AND CIRCUMFERENCE OF

Diam.	Circumferences.								Diam.
	·0	·⅛	·¼	·⅜	·½	·⅝	·¾	·⅞	
0	·0	·3927	·7854	1·178	1·570	1·963	2·356	2·748	0
1	3·141	3·534	3·927	4 319	4·712	5 105	5·497	5·890	1
2	6·283	6·675	7·068	7·461	7·854	8 246	8·639	9·032	2
3	9·424	9·817	10·21	10·60	10·99	11·38	11·78	12·17	3
4	12·56	12 95	13·35	13·74	14·13	14·52	14·92	15·31	4
5	15·70	16·10	16·49	16·88	17·27	17·67	18·06	18·45	5
6	18·84	19·24	19 63	20·02	20·42	20·81	21·20	21·59	6
7	21 99	22·38	22·77	23·16	23·56	23·95	24·34	24·74	7
8	25·13	25·52	25·91	26·31	26·70	27·09	27·48	27·88	8
9	28·27	28·66	29·05	29·45	29·84	30 23	30·63	31·02	9
10	31·41	31·80	32·20	32·59	32·98	33·37	33·77	34·16	10
11	34·55	34 95	35·34	35·73	36·12	36·52	36·91	37·30	11
12	37·69	38·09	38·48	38·87	39·27	39·66	40·05	40·44	12
13	40·84	41·23	41·62	42·01	42·41	42 80	43·19	43·58	13
14	43·98	44·37	44·76	45·16	45·55	45·94	46·33	46·73	14
15	47·12	47·51	47·90	48·30	48·69	49 08	49·48	49·87	15
16	50·26	50·65	51·05	51·44	51·83	52·22	52 62	53·01	16
17	53·40	53·79	54·19	54·58	54·97	55·37	55·76	56·15	17
18	56·54	56·94	57·33	57·72	58·11	58·51	58·90	59·29	18
19	59·69	60·08	60·47	60·86	61·26	61·65	62 04	62·43	19
20	62·83	63·22	63·61	64·01	64·40	64·79	65·18	65·58	20
21	65·97	66·36	66·75	67·15	67·54	67 93	68·32	68 72	21
22	69·11	69·50	69·90	70·29	70·68	71·07	71·47	71·86	22
23	72·25	72·64	73·04	73·43	73·82	74 22	74·61	75·00	23
24	75·39	75·79	76·18	76·57	76·96	77·36	77·75	78·14	24
25	78·54	78·93	79·32	79·71	80·10	80·50	80·89	81·28	25
26	81·68	82·07	82·46	82·85	83·25	83·64	84·03	84·43	26
27	84·82	85·21	85·60	86·00	86·39	86·78	87·17	87·57	27
28	87·96	88·35	88·75	89 14	89.53	89·92	90·32	90·71	28
29	91·10	91·49	91 89	92·28	92·67	93·06	93·46	93·85	29
30	94·24	94·64	95·03	95·42	95·81	96·21	96·60	96·99	30
31	97·4	97·8	98·2	98·6	99·0	99·4	99·7	100·1	31
32	100·5	100·9	101·3	101 7	102·1	102·5	102·9	103·3	32
33	103·7	104·1	104·5	104·9	105·2	105·6	106·0	106 4	33
34	106·8	107·2	107·6	108.0	108·4	108·8	109·2	109·6	34
35	110·0	110·3	110·7	111·1	111·5	111·9	112·3	112·7	35

PAINTING PIPES.

It is desirable to paint pipes for two reasons :—

1. To arrest or prevent oxidation.
2. To give an appearance and finish to the work.

For main or distributing pipes lead paints are the best, as they arrest oxidation and reduce the radiating power. For radiating pipes black japan or black varnish increases the radiating power. When they get dull a wipe over with an oiled woollen cloth will freshen the appearance. If black is too sombre, oxide paint may be used, but not more than two coats, or the efficiency will be impaired.

In churches or public buildings the pipes and coils should be painted to match the walls, dado, or skirting. By this means their conspicuous appearance will be minimized; if painted the same colour as the background, and the joints or bands picked out with the same colour, but a few shades darker, the objection urged about their unsightly appearance will be less frequently heard.

Oxide paints may be had in various shades, if too light, add black paint to get the required shade. If too dark, lighten same by the addition of white lead paint. If a richer tint is required, add vermilion. Mix with turpentine and linseed oil. A little hard drying varnish will enrich the appearance and harden the surface, so that it may be wiped with a dry duster or with a wet sponge, the latter should be followed with a damp chamois leather.

Flat colours are most effective, picked out with darker or lighter shades to harmonize with the wall paper or other surroundings. A good result may be obtained by bronzing any raised ornamentation, or still better ornament with gold leaf. For bronzing with Gold, Silver, Copper, Green, or other bronze, first give the radiator a coat of paint, when dry, go over the parts that are to be bronzed with gold size, applied with a small camel hair brush, when the size is nearly dry, or what is technically termed tacky, apply the bronze dust, also with a dry camel hair brush.

Gilding is done in a similar manner with gold size, cutting transfer gold leaf into strips and pressing with the thumb on to the sized parts. Another method of gilding is with a tip and cushion, but this is usually the work of an expert.

PIPES (IMPROPERLY FIXED).

Failures from this cause are by no means uncommon. The following are a few out of many that have come under the notice of the writer :—

1. Boiler of small apparatus fixed above the level of circulating pipes, the water in the boiler could be made to boil, causing a kicking and thumping noise, but would not circulate through the pipes.

2. In a range of six greenhouses the main pipes were dipped under the doors of each house; the water would circulate in the first four houses, and although the boiler was five or six feet below floor levels, no amount of firing would force the water through the two end houses until the pipes were re-arranged.

3. Schools and class-rooms where some of the pipes would get intensely hot, while others could not be warmed, and many other similar cases.

In large buildings where a number of rooms have to be heated independently (especially where the floors are on various levels) a certain amount of experience and judgment is required to give satisfactory results. Depend upon it that every defect arises from some cause for which a corresponding remedy may readily be found.

PIPES (OBSTRUCTION IN).

Causes of obstruction are various, such as air, mud deposit, incrustation, cotton-waste, shavings, flash of metal, ice, &c.

The accumulation of air is one of the most common and one of the most annoying, because a little forethought, and the fixing of air vents where necessary, would prevent it.

A deposit of mud or sediment depends chiefly on the quality of water used; with foul or dirty water a deposit accumulates which, if not sufficient to prevent the circulation, will retard it, and minimize the efficiency of the apparatus, for mud inside, or dust outside of a pipe acts as a non-conductor, and prevents the proper radiation of heat. In an apparatus that is used for heating purposes only, (and not for drawing off quantities of hot water) these deposits result from the accumulation of many years of active service.

Incrustation is an enemy that is only too common in steam boilers, and in hot-water boilers where large quantities of hot water are constantly drawn off at high temperatures; it is seldom met with in boilers used for radiating purposes only, and where the water is rarely changed. Further reference is made to this under Bath Apparatus.

It may appear incredible that cotton-waste, shavings, or materials of a like nature should be the cause of obstruction; workmen are not infallible, and in numbers of instances substances of this kind have been temporarily placed in the mouth of a pipe to prevent brickdust or other rubbish falling in, and through some carelessness or oversight, the pipes have been jointed, and the obstruction discovered after ineffectual attempts to get up circulation, necessitating the unjointing and refixing of portion of the apparatus.

Flash of Metal.—Obstructions from this cause are rare, and ought never to occur; they are sometimes found in a double bend or casting of some special form or projection, which has been made with makeshift cores, *i.e.*, the sand core is made in two parts instead of one, and when laid in the mould one or more cores are displaced by the weight of the hot metal, and a thin film or flash of metal is run between the two cores, thus blocking the passage. This should be discovered when the casting is dressed or tested, and it is only through gross carelessness that a casting of this kind is allowed to leave the foundry.

Ice in Pipes.—The effect of severe or excessive frost in converting the water contained in pipes into solid ice is often the cause of much trouble; this happens much more readily in pipes of small diameter, say, under two inches. In exposed positions pipes 4 inches diameter or even larger are liable to like results if not in use. The supply-pipe, or the air-pipes, are affected first, and when any apparatus is started during time of frost, care should be taken to see that these are all clear.

The following extract from a lecture delivered at the London Institution in March, 1886, by Professor T. G. Bonney gives a forcible illustration of the effects of frost:—"The summits of all mountains are strewn with fragments of rock, which have been split off from larger masses by the various changes in temperature which are experienced on the tops of mountains. From the gain and loss of heat to which the rocks are exposed there arises a constant strain in the way of contraction and expansion. The sides and summits are further chipped about by the power of frost. Water in freezing expands very considerably, 1,000 cubic feet of water expanding to 1,102 cubic feet of ice, and the force which is created by that expansion is exceedingly great. Experiments have been made with stout bomb shells, and on their being filled with water and exposed to the influence of frost it was found that the force of the expansion was sufficient to burst the strongest shell. This power was at work on the Alps day and night, and caused those constant showers of stones which all who travel there must have observed."

The expansion given above is about 1 in 10, or ten per cent.; other authorities give 1 in 12, or 8½ per cent., and the force thus exerted is sufficient (when the water is confined or sealed) to burst the strongest pipes; if the joints are rigid the sockets will be burst, or the pipes split longitudinally or broken through. I have known a coil or stack of ten pipes broken from top to bottom as clean as if cut with a saw, showing a solid block of ice in each pipe. I may here mention that the effect of this expansion where Jones's Expansion Joints and Coils are used is simply to push off the end connections or the coil ends without bursting any pipes or other castings, and when the frost appears they can be rejointed at a very trifling cost.

CHAPTER XV.

STOKING. SUPPLY CISTERNS. TOOLS.

The efficiency of an apparatus depends very much upon the stoker or person who sees to the firing; if careless or negligent he may use a large quantity of fuel, and yet get poor results; the following **instructions for working** a hot-water heating-apparatus may be helpful:—

1. See that the apparatus is filled; the supply-cistern should contain about three inches of water when cold, leaving the rest for expansion.

2. See that the boiler and flues are all clean and free from soot.

3. Before starting the fire cover the fire-bars with rough fuel.

4. Throw on light fires, and often, until the pipes are all hot; then regulate damper in chimney and air-register of ashes-door, and work with a slow fire.

5. Avoid forced firing; it is wasteful.

6. Avoid thick fires unless banking up for the night.

7. Air-taps (if any) should be frequently opened. If hot water or steam is forced through the air-pipes, check the fire by closing the damper.

8. The fire-door should never be left open while apparatus is working.

9. If the water in supply-cistern becomes hot, or overflows in large quantities, it indicates excessive firing; the damper should be closed at once, and the apparatus filled up with water.

10. If smoke issues from fire-door, open damper; if the smoke continues, clean out the flues.

11. Churches and chapels should be warmed on Saturday, the fire banked up at night, the pipes well heated before service; the fire reduced and the pipes cooling down when service commences.

12. Keep apparatus constantly working in times of frost.

SUPPLY CISTERN.

The overflow of water from the supply-cistern arises from two distinct causes:—

1. If the capacity of the cistern be too small, or if it contains too much water, it will be forced over by the expansion as it becomes heated.

The cistern should be of sufficient size to hold about one-twentieth part of the water contained in the whole of the apparatus (see "Expansion of Water," page 16).

Example.—Suppose the apparatus has 1,000 feet of 4-inch pipes, the quantity of water would be about 500 gallons, and a 25-gallon cistern would be required.

Whenever the apparatus is filled the bottom of the cistern should be covered to the depth of a few inches only. If a ball-tap is attached, it should be placed as near the bottom of the cistern as possible, to allow for the expansion of the water when heated.

2. **The second cause** of overflow is more serious; the water in the cistern becomes hot (which it should never do), and swells over suddenly, in quantities sometimes sufficient to empty the flow-pipe and stop the circulation, when steam will be generated and escape from the air-pipes until the fire goes down, or the apparatus is emptied. This may be brought about by the supply-pipe being wrongly connected, or if the power of the boiler is excessive, or from over-firing.

The supply-pipe should not be less than 1 inch, and should be connected to the underside of the return pipe, as in Fig. 56, or with a syphon-pipe, as in Fig. 57, or direct to the bottom of the boiler, but should in all cases be provided with syphon or double bend; the cause of complaint will thus be prevented.

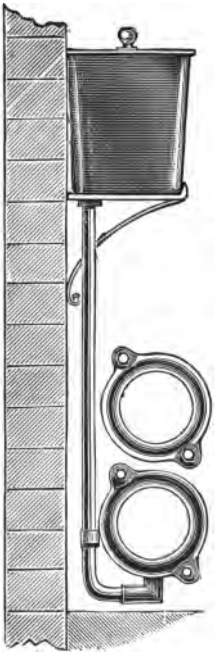


Fig. 56.

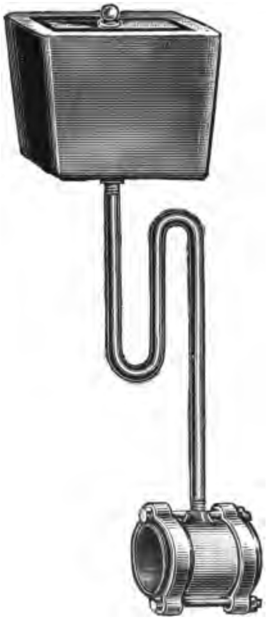


Fig. 57.

TOOLS.

The Proverb says, "Neither wise men nor fools can work without tools." Make-shift work is invariably the most expensive in the end. It is not necessary to enumerate or describe the various tools required by hot-water engineers, but in these days of keen competition and lightning despatch, the best appliances for executing work neatly and expeditiously are important considerations for employers. Whether it be a vice, file, or chisel, screwing tackle, or any other description of tool, let it be the best of its kind, and do not give the workman the opportunity to find fault with his tools.

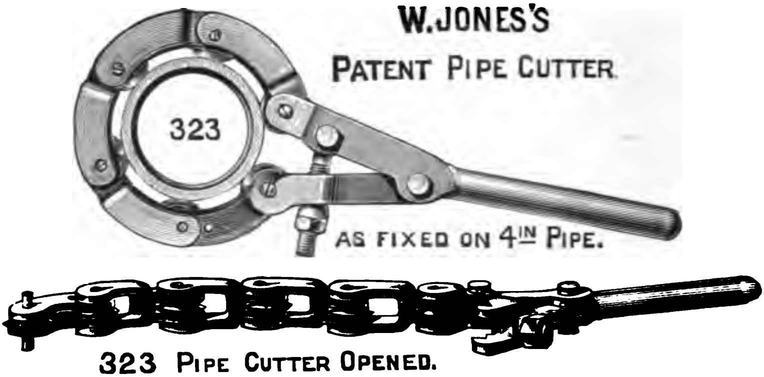


Fig. 58.

The pipe-cutter (Fig. 58) is a labour-saving tool that will speedily repay the first cost to anyone who has much pipe-fixing to do. It cuts wrought or cast pipes evenly and quickly, is readily adjusted to pipes of different diameters, it requires only a short stroke, and may be used in confined spaces.

CHAPTER XVI.

VALVES.

There are two classes of cast-iron valves—throttle, and perfect, or screw-down. Both kinds are made of various patterns and designs.

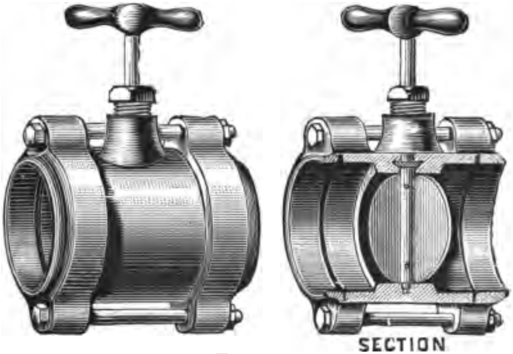


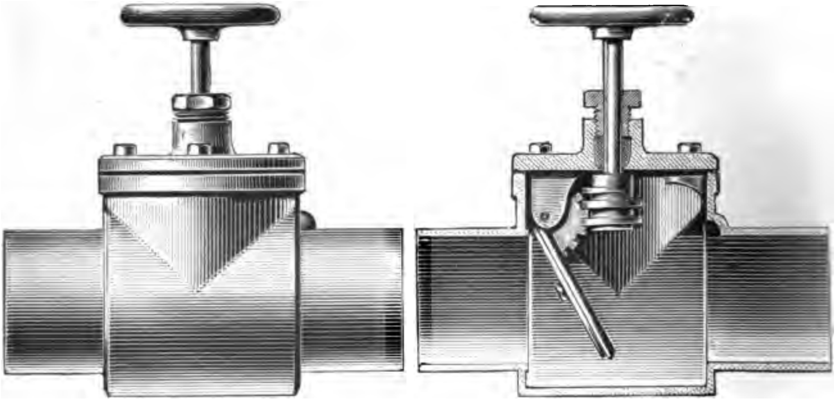
Fig. 59.

THROTTLE-VALVE.

The throttle-valve (Fig. 59) is simple in construction. The body is made of cast-iron, the inside diameter being bored to get a true surface; the baffler, stalk, handle, and packing-nut are generally brass or gun metal. The edge of the baffler or plate is turned, and after being carefully fitted, is attached to the stalk. By a quarter turn of the handle the valve is full open.

This valve is not absolutely watertight, but, if properly fitted, is sufficient to check the circulation, although it cannot be regulated to the same nicety as a screw-down valve. Its comparatively low cost, and simplicity of construction account for its frequent adoption.

Valves should be fixed in flow and return pipes, or the water will back up the return. In a range of houses it is very desirable that valves should be so arranged that each house may be heated independently. When valves are badly fitted they are practically useless, for the smallest aperture will allow the water to pass a considerable distance along the pipe. When lofty buildings are heated on the various floors, or where water is scarce or not easily obtainable, screw-down valves are decidedly the best. Sometimes a slight leak occurs at the stalk through the packing; this is easily rectified by tightening the brass nut, or by the addition of a little hemp packing.

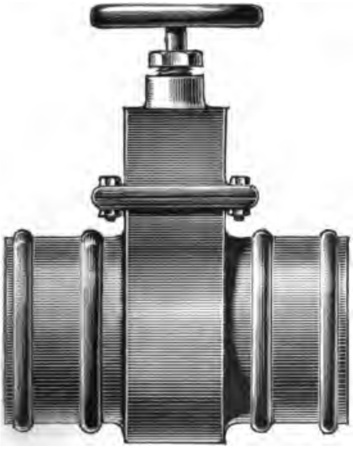


SCREW DOWN VALVE
Fig. 60

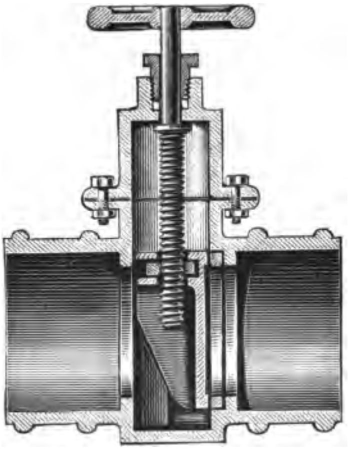
SECTION
Fig. 61.

SCREW-DOWN VALVE.

The screw-down valve (Fig. 60 and 61) is different in construction, and is more expensive than the throttle. The seating is machine faced; a rubber ring is attached (by means of a plate and screw) to a brass quadrant, which is opened by a worm or screw; at the top of the spindle is fixed a hand-wheel, marked with arrows indicating the direction in which the wheel should be turned in order to open or close the valve; the compression of the rubber ring on the faced surface of metal makes it perfectly water-tight. This valve should be occasionally opened and closed, or the rubber may adhere to the metal and get deranged, in fact all valves should be periodically examined, and the spindles oiled, &c., to see that they work freely, and that there is no leakage at the packing-nuts, &c.



SCREW SLIDE VALVE.
Fig. 62.



SECTION.
Fig. 63.

The screw-slide valve (Figs. 62 and 63) has no rubber ring, the valve and the seat are made of brass, the surface of each being turned and the faces ground. Instead of hinging on a quadrant, the valve is lifted vertically by means of a double-threaded screw, and when closed is forced by wedge-shaped projections against the valve seat, making a good and reliable joint. This valve (as also Fig. 61) gives a clear passage the full bore of the pipe. For first-class work they are preferable to the ordinary throttle-valve. When used for steam, metal surfaces are best, as rubber is liable to harden from intense heat ; on the other hand, metal faces, unless carefully ground, are liable to leakage, and are sometimes affected by grit or dirt getting between the valve and the valve seat.

Valves similar in construction are often made with double faces ; these are called sluice valves ; as they are generally used for water mains, and to withstand excessive pressure, they need not be further described here.

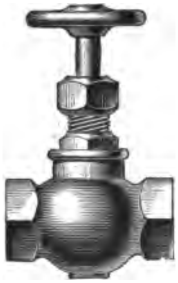


Fig. 64.

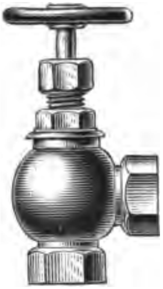


Fig. 65.

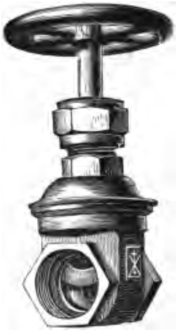


Fig. 66.

GUN-METAL VALVES.

For wrought tubes gun-metal valves are most suitable. The ordinary wheel valve (Fig. 64) is too well known to need any description, it is adapted for either hot water or steam; the valve should have wings on, otherwise it is liable to bear on one edge of the seating only, especially when fixed in a vertical pipe, and when this happens it is liable to leakage.

The angle valve (Fig. 65) is the same in principle, and is specially suited for radiators or coils. For first-class work nickel plating adds to the finish and appearance, and repays the slight extra cost.

Fig. 66 is Peet's patent full way double-faced valve, and is preferable for water circulation, as it has a clear full-bore passage throughout, and it is a good reliable valve.

CHAPTER XVII.

CHURCHES, PUBLIC BUILDINGS, &c.

One of the principal difficulties in heating churches or other lofty buildings is in providing and distributing sufficient radiating-surface to heat the building efficiently, and yet interfere as little as possible with the furnishing and the architectural features of the building. It is difficult to lay down hard-and-fast lines that will apply equally to every description of building.

The following suggestions will be found generally applicable :—

1. Ascertain the cubic capacity of the building.

2. Find the total quantity of pipes required, including mains.

3. Select a good boiler of ample power.

4. Distribute the pipes as far as possible over the whole of the building.

5. If sufficient heating-surface cannot otherwise be obtained, coils or stacks of pipes may be used. These should be fixed near the entrances, underneath large windows, and in the least conspicuous places. They are frequently surrounded (for the sake of appearance) with ornamental coil-cases. When a large heating-surface is required in a limited space radiators are often substituted. *(See Chapter* 18, *Coils and Radiators).*

6. For horticultural buildings, where a regular and uniform temperature has to be maintained, 4-inch pipes are the best.

7. For churches or other buildings, where occasional or intermittent work is required, 2-inch or 3-inch pipes are

preferable. They are neater in appearance, hold less water, and the temperature will be raised in a shorter time. In aisles or passages 2-inch wrought-iron pipes give a neater appearance than cast, and are well worth the slight additional cost.

8. Avoid dips under doorways, &c.

9. Avoid channels as far as possible. About 20 to 25 per cent. more piping will be required to give equal results. The channels form a receptacle for dirt, the pipes get covered with dust, thus impairing their efficiency, and the channels and gratings add considerable to the first cost.

10. In churches, schools, &c., an apparatus (for the average English climate) ought to be capable of raising the temperature about 25° or 30° above the outside temperature, say, 55° to 60° inside when the outside temperature is 30°. In America they usually adopt 70° inside when zero outside.

There is little or no difficulty in warming churches or other public buildings, but judgment and discretion are necessary to arrange the pipes so that there shall be a free circulation, and so that they shall be effective without being conspicuous.

In lofty buildings one of the greatest difficulties is to prevent down draughts of currents of cold air, and this tendency exists in all lofty buildings, whether they are heated by high or low-pressure hot water, by steam, or by hot air ; the greater the difference between the inside and the outside temperature, so, in proportion, will the tendency to down draughts be increased, and the higher the temperature of the pipes or the hot air the stronger will be currents; hence the low-pressure system is the best, because a larger heating surface is presented at a milder or more humid temperature. You may frequently see persons looking up at the roof, ceiling, or windows to find where the draught comes from, when the cause is from a totally different source. If the pipes are intensely hot the currents of heated air will ascend more rapidly, and displace in the same relative proportion the colder air in the upper part of the building, and these currents are very objectionable. These difficulties may be minimized by a thorough distribution of the pipes, and by following the instructions given under the head of "Stoking," Chap. xv.

The following simple test will forcibly illustrate the effects of these currents to anyone sufficiently curious to try the experiment.

Stand in a warm room on a cold day, and puff a cloud of smoke from a cigar or cigarette against the window-pane, and the smoke will instantly fall ; give another puff about 6 to 9 inches away from the glass and it will rise slowly. This is caused by the radiation of cold air from the cooling effects of the outer air on the glass, thus causing a down current, and the draught is often sufficiently strong to be perceptible on the head and shoulders of any person sitting near the window.

An excellent plan (and it is surprising that it is not more frequently adopted) is to have the windows double-glazed, leaving an air-space of 1-inch to 3-inches between the panes ; this air acts as a non-conductor, thus preventing the heat going out or the cold coming in ; and I have known instances where this simple plan has been tried in exposed rooms with a north-east aspect, and a difference of 7° to 10° in the temperature of the room has resulted.

I have for years had an impression that these objectionable down draughts could be counteracted, if not entirely prevented, and have prepared plans of a boiler and system of heating with a view of effecting this desirable object. The principal features of the system are to heat with *high-pressure* tubes the upper strata of air, and to put *low-pressure* pipes near the floor, both systems heated from one fire. The first cost would be slightly increased, but the permanent saving of fuel, and the increased comfort would more than compensate for the outlay.

It is frequently stated by engineers who make a speciality of high-pressure apparatus that this system is more economic than the low-pressure, and that the heat can be raised in a much shorter time. A good deal depends on the relative quantities of pipes to the cubic capacity of the building, and the proportion of boiler-power to the length of pipes to be heated, also as to the manner in which the boiler or coil may be set so as to absorb as much of the heat as possible before it reaches the chimney.

First, as to the consumption of fuel. The writer has found in a variety of tests and experiments that the results are favourable to the low-pressure apparatus, and that better results are obtained for a given quantity of fuel, and he has no hesitation in stating that a given amount of boiler-surface *low-pressure* will give better results than the same amount of surface of a *high-pressure* boiler, all other circumstances and conditions being equal. In proof of this he may mention a lofty church, with a capacity of 176,000 cubic feet, heated with about 1,900 feet of 3-inch pipes, and a check-end saddle-boiler, with waterway bridge, the total cost of fuel for the whole of the winter being £5, and he would be glad to hear of any church of equal size being warmed at the same cost either by high-pressure, hot-air, steam, or by any other system.

Second, as to the time occupied. It is true that a given length of piping of a high-pressure apparatus can be heated in a shorter time than the same length of 2-inch or 3-inch low-pressure pipes, owing to the smaller quantity of water contained in the ⅞-inch pipes; but it does not follow that the building will be warmed in a proportionately short time, for the following reasons:—

1. To maintain a given temperature with $\frac{7}{8}$-inch bore tubes they will require to be about 40 per cent. longer than the 3-inch low-pressure pipes.

2. Although the pipes are heated quickly, they also cool quickly, and fluctuate considerably with every slight change of the fire.

The result of two tests are given below, both in chapels of nearly equal size, one heated with high and the other with low-pressure apparatus :—

HIGH PRESSURE.		LOW PRESSURE.	
Capacity of chapel, 45,000 cubic feet ; length of $\frac{7}{8}$-inch-bore-tube 680 feet ; length of $\frac{7}{8}$-inch-bore tube in boiler, 64 feet. *Outside Temperature*, 32° *Fahr.*		Capacity of chapel, 43,000 cubic feet. 470 feet of 3-inch pipes. *Outside Temperature*, 34° *Fahr.*	
Fire Started	Inside Temperature	Fire Started	Inside Temperature
10-0 A M.	40°	9-30 A.M.	38°
12-30	50	11-30	46
1-0	54	12-30	52
2-0	55	1-30	54
3-0	56	2-30	55
4-0	57	3-30	56
5 0	58	4-30	58
6-0	60	6-0	62
Temperature raised in 8 hours	20°	Temperature raised in 8½ hours	24°

It will be manifest from the above tests that the high-pressure theory is not established by facts. The writer regrets that the weight of fuel was not taken in each test. Although he may have his own opinions on this point, he would hesitate to assert anything that he could not verify should occasion require.

A very important feature with low-pressure heating is the immunity of risk from fire. The following quotations from various sources are very significant. Many others of a similar nature could be quoted if necessary.

"Within the last nine years nearly 800 churches have been burned in America, mostly through defective heating apparatus. The same cause has also proved very destructive on this side of the Atlantic."—*Christian World*, April 17th, 1884.

"A fire occurred in St. Thomas's Church, Stourbridge, through the over-heating of a flue in connection with the hot-air apparatus used for warming the church, and but for the timely discovery of the fire serious damage would have been done. A new departure has been made, and a hot-water apparatus has been supplied for heating the building." —*Brierley Hill Advertiser*, Aug. 25th, 1883.

"Another serious fire has occurred in connection with a place of worship. The Presbyterian Church at Hanley, in Staffordshire, was discovered to be on fire early on Sunday morning, and the fire was not subdued until the fire-brigade had played upon it for nearly two hours, during which time the pulpit and seats in its vicinity were completely demolished. The significant statement is made that 'overheating of a flue caused the fire.' When will managers of churches and chapels be wise enough to use hot-water instead of hot-air? There can be no question as to the safety and healthfulness of the former over the latter. We should be sorry to attend a church heated with hot-air! People must not be expected to submit to manifestly injurious physical conditions for ever so eloquent and excellent a preacher."—*Christian World*, January 18th, 1883.

"Dr. Standish was driving by the Wesleyan Chapel, Old Hill, last evening, and noticed flames inside. An alarm was raised, and it was discovered that a fire had broken out. Assistance being rendered, the flames were speedily subdued. The fire originated by some mats igniting which the caretaker had placed on the heating-apparatus while cleaning the chapel."—*Birmingham Daily Mail*, March 10th, 1886.

" The congregation of St. Augustine Church, George IV. Bridge, Edinburgh, met on Sunday again for the first time in the church since the interior was partially destroyed by fire a month ago. The necessary restoration works have not only been made, but the interior of the church has been decorated. The old hot-air heating arrangement, which was responsible for the fire, has now been replaced by low-pressure hot-water apparatus."—*The Building News*, Dec. 25th, 1891.

In further confirmation of the fact, many insurance companies increase their premiums on places heated with high-pressure or hot-air, &c., and quote minimum rates when heated on the low-pressure system.

For the prevention of fires avoid—

Horizontal flues underneath wood floors.

Joists, beams, wood floors, &c., coming in contact with chimneys or flues.

Placing wood or other inflammable material on, or directly over, boiler or flues.

Iron chimney pipes in contact with, or close to, woodwork.

Accumulation of gases in flues that explode when ignited.

Hot ashes or clinkers, when cleaning out the fire, mixing with slack or other fuel.

* * *

CHAPTER XVIII.

COILS, COIL CASES & RADIATORS.

What are Coils? What are Radiators? What is the difference between them? What purpose do they serve?

In a sense all Coils used for heating purposes are Radiators, but it does not follow that all Radiators are Coils, and to prevent confusion of ideas I will endeavour to answer the above questions and to explain briefly the purpose they serve, the difference in construction, and the advantages they possess.

The primary object is to get the largest amount of heating or radiating surface in the smallest possible space, so that they may be fixed in places where long ranges of pipes would be objectionable, either on account of the space occupied, or their unsightly appearance.

We will consider Coils first, as they were first used.

Coils are sometimes formed of wrought steam tubes, bent into a rectangular spiral form as Fig. 67,

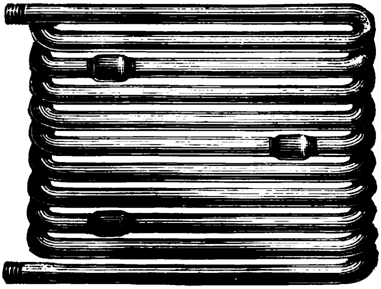


Fig. 67.

or they are formed with straight tubes, with double bends or siphons into what is commonly called a grid iron coil, these are more frequently used when heating by steam.

The cast iron Coils first introduced were made with socket or flanged pipes, and siphons or return bends as Figs. 68, 69.

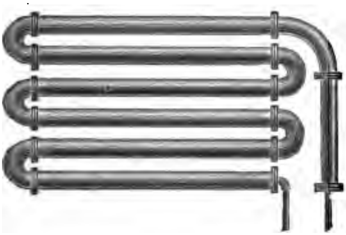


Fig. 68.

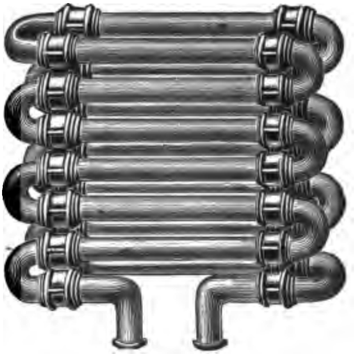


Fig. 69.

Next followed Box Ends, with sockets into which the pipes were caulked, there are two kinds of box end socket Coils, the one having internal sockets, (see Fig. 70),

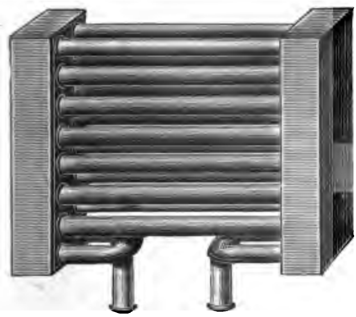


Fig. 70.
INTERNAL SOCKET COIL.

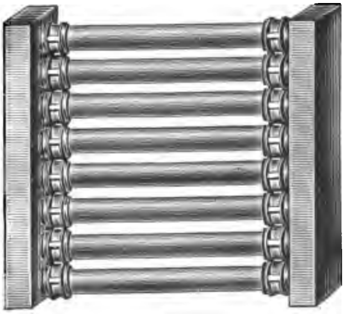


Fig. 71.
EXTERNAL SOCKET COIL.

i.e. the sockets do not project beyond the face of the Coil, the other has external sockets, which project from the face of the Coil Box as in Fig. 71.

The principal objections to Coils of this description are their unsightly appearance, the difficulty of making good tight joints, and the still greater difficulty of repairs in case of accident.

Next in order followed Ornamental Coil Boxes with raised ornamentation or with recessed panels, intended to minimize the unsightly appearance, but compared with the Radiators now in use they are all heavy clumsy appliances.

Some of the objections to Socket or Flanged Pipe Coils have been overcome by the introduction of Coils in which the joints are made with rubber rings, that are compressed with bolts and nuts.

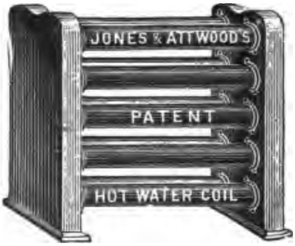


Fig. 72.

Fig. 72 is a Coil of this description, (invented by the writer in 1876), possessing some important features among which are the following:

They can be fixed quickly by inexperienced persons. All pipes are plain, and readily cut to special lengths. Any pipe may be replaced without disturbing the others. They are low in price, and can be readily connected to any heating apparatus, but should not be used where the head of water exceeds 30 feet, as they are not suitable for heavy pressures.

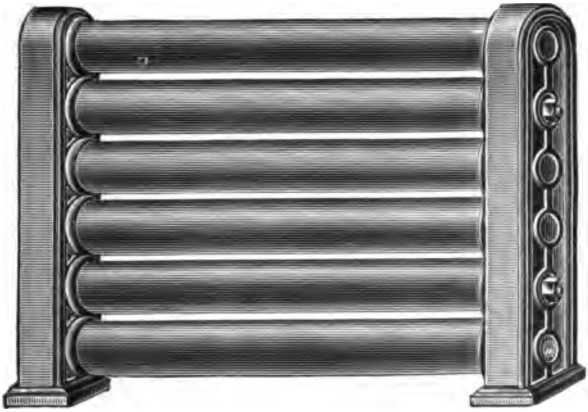


Fig. 73.

RUBBER JOINTED COIL.

Fig. 73 is adapted for any pressure up to 100 feet head, and is suitable for lofty buildings, it is strong, neat in appearance, the pipes are machine faced to the required length, the joints are made by compressing the rubber rings between the faced ends of pipes, and recesses in the coil ends with two or more bolts running through the entire length of the Coil.

The Coils previously described are suitable for plain work, such as for public buildings, schools, factories, &c., and when used for entrance halls, dining rooms or other positions where the appearance or finish is important, they should be covered or hidden from view by coil cases or hall tables, such as Fig. 74. These are supplied in various designs, either with cast tops, or with enamelled slate or marble tops as may be preferred.

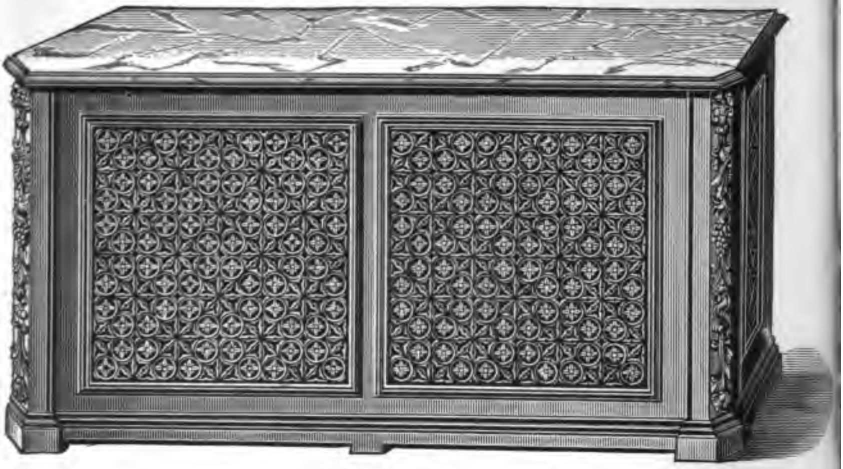


Fig. 74.

Radiators are without doubt a vast improvement upon the heating appliances hitherto used in this country, we are indebted to the Americans for their introduction, and some of the English firms have not been slow to appreciate the value of these modern introductions.

I have been in correspondence with many of the leading makers in England and America, with a view to ascertain as far as possible when, and by whom Radiators were introduced; and whilst acknowledging the courtesy of these firms for the information they have given, in some cases it has been of such a vague nature that it is difficult to state positively the exact order in which the various forms of Radiators have been brought into public use.

When soliciting information from what appeared to me the most reliable sources, I stated that it was for use in this pamphlet, if any inventor or maker has been overlooked it has not been intentional, and I shall be perfectly willing in any future issue to make additions or corrections should any reasonable proof be given that the information is reliable.

The earliest mention of Hot Water Radiators that I have been able to trace is one patented in the United States, March 9th, 1858, by Thomas T. Tasker, of Philadelphia, it consists of two or more series of tubes, called sections, which are joined or fitted to each other by means of flange joints, and bolts passing through the sections and tightened by nuts. It is clumsy looking and little if any improvement on the box end coils.

Another patent for Steam Radiators is by William B. Snow, of Brooklyn, dated August 17th, 1875, and consists of two or more independent vertical sections, which are secured with 1in. wrought gas tubes and nuts (instead of through bolts) the gas tubes are perforated with small holes to let steam pass into each section, and to allow the water from condensation to escape, the joints between the sections are formed with rubber rings compressed into a shallow socket by a short projecting spigot, and the whole tightened up with nuts on the ends of the 1in. tubes before mentioned.

A Radiator for hot water or steam was patented by L. D. C. Wood, of Brooklyn, May 2nd, 1876, and consists of a number of groups of pipes or cast sections, connected at the top and bottom by means of short tubes provided with right and left hand threads adapted to similar threads in the heads of the various sections.

The great impetus given to the American Radiator trade appears to be due to the introduction of the Bundy Loop Radiator by the A. A. Griffing Iron Co., Jersey City. I quote their own words.

"Radiators were introduced in America before they were in England, immediately following the use of wrought iron pipes for heating comes the ‘Bundy’ Radiator, the first consisted of an iron base into which were screwed wrought iron pipes 2½ft. long, with cap screwed on top of them, and all surmountnd with a fret work top.”

“The first cast iron Radiator was invented and patented by Nathaniel H. Bundy, on September 22nd, 1874, which was described in a small leaflet, the “Bundy” Radiator has a world-wide reputation and requires a 272 page book to adequately describe the great variety now in use. (See Fig. 75).

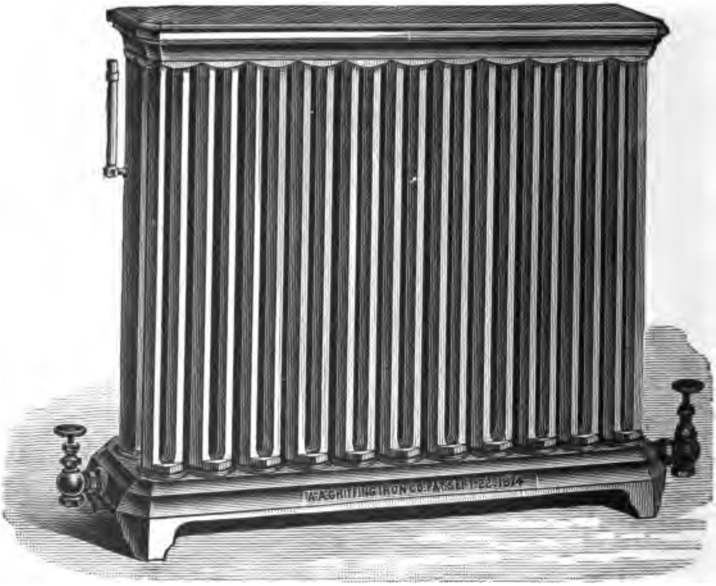

A.A.GRIFFING IRON CO. PAT. SEP. 22 1874

Fig. 75.
“BUNDY” RADIATOR.

Sectional Radiators were patented by R. S. Gillispie, July 3rd, 1877, this company owns the exclusive rights under which the “Elite,” the “Triumph” and the “Pyro” Radiators are made.’

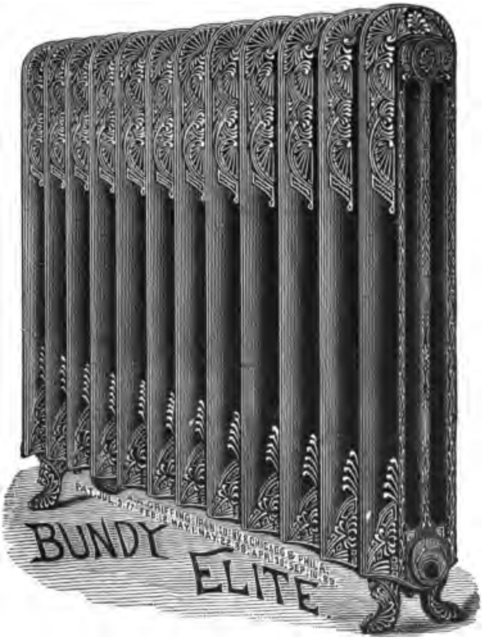


Fig. 76.

The American Radiator Co., Chicago, say "Steam and water appliances are used for heating purposes to a greater extent in America than in England, due largely to the difference in climate. The manufacturers have by their enterprise and advertising, educated a tremendous number of steam fitters, who are competent to erect first-class heating plants, thus placing in the field a large army of missionary workers for educating the public to the benefits of steam and water as mediums of heat. We melt about 150 tons of iron per day all of which goes into cast iron Radiators. All Radiators made at our 'Pierce' plant (excepting 'Ideal' hot water) are connected with right hand screwed nipples, or slip nipples, those made at our Detroit plant are connected with right hand screwed nipples. Our 'Ideal' Water Radiators are connected with right and left nipples which are screwed into place with wrench applied to the outside, they are also made so that the nipples may be screwed by a wrench applied to the inside if so preferred."

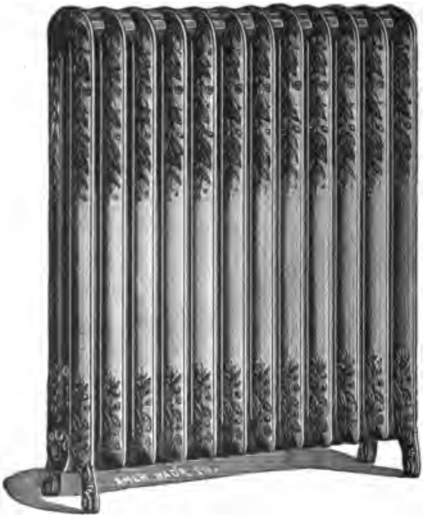


Fig. 77.
IDEAL RADIATOR.

Messrs. Bartlett, Hayward & Co., of Baltimore, say "We have been erecting heating apparatus for over half a century," but the records of this firm have not been preserved in such a shape as to be authentic as to dates."

The Gurney Hot Water Heater Co., Boston, say "We believe Messrs. Bartlett, Hayward & Co., and A. A. Griffing Iron Co. were about the first, next the 'Union' Radiators made by H. B. Smith Co., Westfield, Mass., which were put together by what is known as the push nipple joints, the original inventors of Steam Radiators in this country were we believe, Nason of New York, and the Walworth Manufacturing Co., of Boston. Within the last six or seven years hot water radiation has increased 60 per cent., previously the output was mostly for steam, we are informed by one of the leading manufacturers that out of his sales for last year, 60 per cent. was for hot water."

H. B. Smith Co., Westfield, Mass., U.S.A. say "We have been in the business since 1833, and stand as one of the oldest firms in this country as manufacturers of apparatus for the warming of buildings. We introduced our 'Whittier' Radiator in 1873, this has now been relegated to the rear in the march of improvements. The next was the 'Reed' Radiator, patented by the President of our Co., Mr. John R. Reed, these we are now manufacturing, they were placed upon the market about 1876, and are intended only for steam. The 'Union' Radiators are made in separate sections, the joints between the sections are made by a small taper wrought iron smooth nipple, which is placed between the sections, and the sections then forced together making a tight durable joint.'

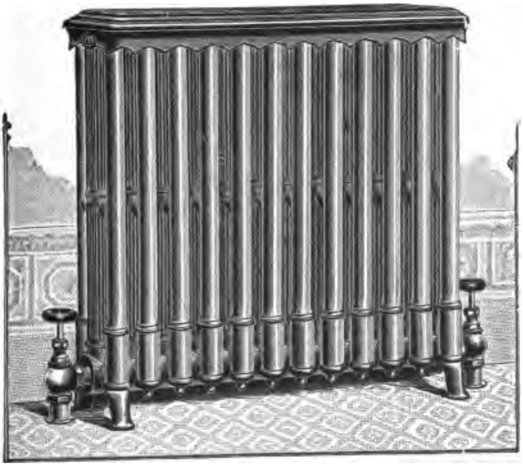


Fig. 78.
UNION RADIATOR.

Among the first Radiators patented in England may be mentioned the following.

James Keith's	patent	No. 1920 in 1882.
Do.	do.	No. 3063 in 1887.
W. G. Cannon	do.	No. 8395 in 1884.
A. Waters	do.	No. 15042 in 1884.
T. A. Heaps	do.	No. 5971 in 1887.

Many other Radiators have been introduced by English makers during the past ten years. I will give the opinions and remarks quoted by some of the best known makers.

Messrs. Longden & Co., Sheffield, say "We are not sure who first introduced Radiators into England, but they were first brought into general use by us, Steam Radiators are of American origin. Water Radiators are English and more recent."

Messrs. Rosser & Russell, of London, say "We are the original inventors of the Ventilating Radiator" ; but they do not give the date.

The Thames Bank Iron Co., say "We brought out a ventilating Radiator some years ago, the air tube was brought up the centre of that containing the water, we cannot say whether we were the first to introduce them."

Mr. Richardson of the Meadow Foundry Co., Ltd., Mansfield, says "I believe Messrs. Weeks & Co. first introduced Ventilating Radiators (so called), and that Messrs. Wenham & Waters followed. I struck out a line for myself, and made a new departure by which I doubled the radiating surface on the same base, (see Fig. 79).

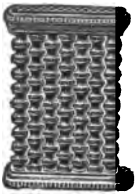
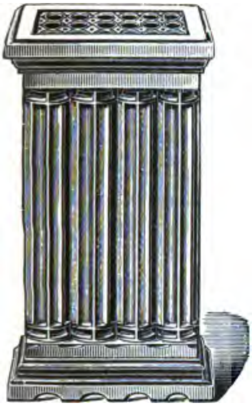


Fig. 79.

I have proved beyond doubt that the solid projections of the ribbed Radiators are less effective than the body or pipe surface."

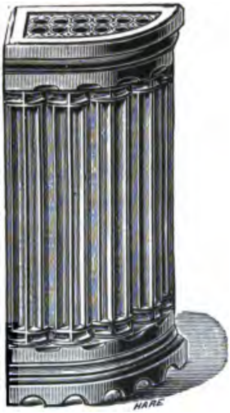
The views expressed by Mr. Richardson as to the value of gills or ribbed surface are confirmed by the writer's experience also, as I have found them less effective than the metal surface that is in contact with the water.

The Beeston Foundry Co., Beeston, have patterns of flat, round, square, and corner Radiators.



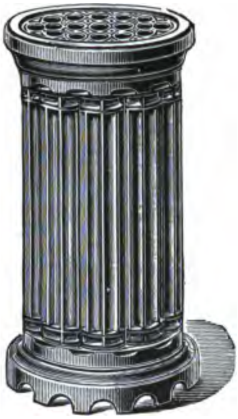
Square Radiator

Fig. 80.



Corner Radiator

Fig. 81.



Circular Radiator

Fig. 82.

Mr. James Keith's "Universal" Radiator is in one respect unique, I believe it is the only Radiator that is cast in one piece, and it is claimed that having no joints there is less liability of leakage. See Figs. 83 and 84.

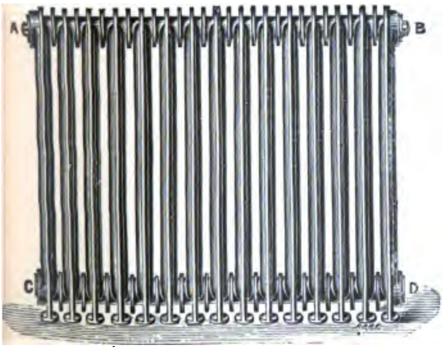


Fig. 83.

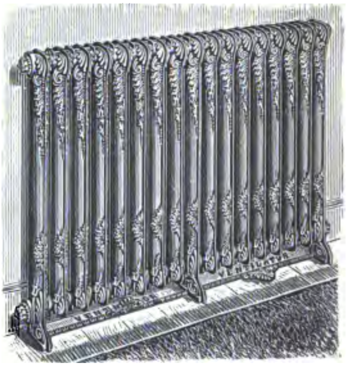


Fig. 84.

The Ventilating Radiator, Fig. 85, was introduced by the writer in 1881, and was awarded a Silver Medal in the same year, it is different from any Radiator in the market, the body and the ventilating tubes being made of wrought iron, the caps and bases are cast, it is adapted for the centre of a hall, or the corners of a room, and affords good scope for decoration. By fixing a channel or air duct from outside to the underside or base of Radiator, a good current of pure warmed air is introduced, thus affording ventilation as well as heating.

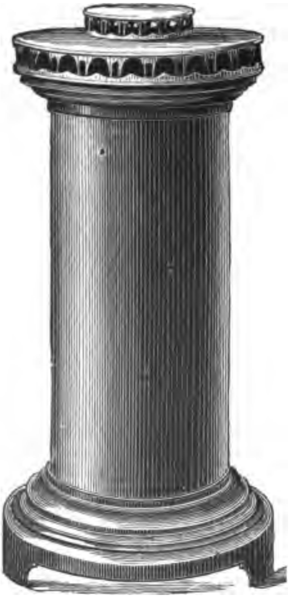


Fig. 85.

Now the principal advantages of Radiators may be briefly summarised as follows :—

A large heating surface is concentrated into a limited space.

They are more ornamental and neater in appearance than ordinary Pipes or Coils.

They can be cleaned and kept free from dust more readily than Coils under Coil Cases.

They are suitable for Art Galleries, Libraries, Museums, and any class of building where the first cost is not an important consideration.

The Radiators previously described are commonly called " Direct " Radiators, but others are extensively used in America that are described as indirect, and direct-indirect.

These are used for the purpose of ventilation combined with heating, the **direct-indirect** is fixed inside the room that has to be heated, and air ducts or chambers are constructed so as to bring a supply of fresh air from the

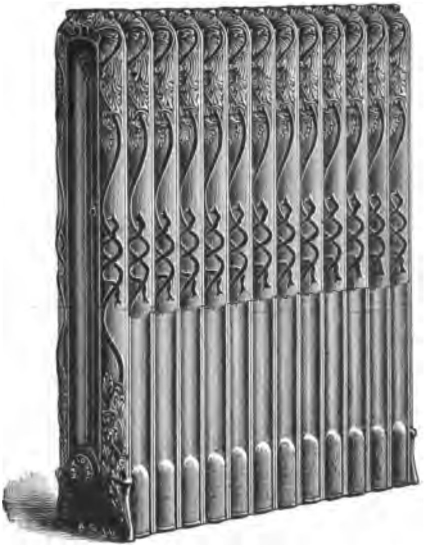


Fig. 86.
" NATIONAL " DIRECT-INDIRECT RADIATOR.

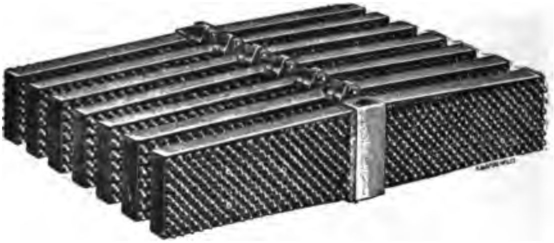


Fig. 87.
INDIRECT PIN RADIATOR.

outside in such a manner that the impact of the incoming air strikes against the radiator surface as it enters the room. See Fig. 86.

The Indirect Radiators are usually fixed in basements or rooms below the level of those that are to be heated, and fresh air chambers are constructed to convey the heated air into the rooms to be heated, this is an excellent system of heating and ventilating, but requires a definite arrangement of inlet and exit flues, these can readily be provided in a new building, but would be costly and troublesome to adapt to an existing building, especially when a number of rooms on various levels require to be heated.

As there is a constantly changing supply of air introduced, the heating surface has necessarily to be largely increased according to the temperature required, and the time in which the air in the room is changed, in ordinary rooms the contents (in cubic feet) of air may be changed once an hour, in a schoolroom twice an hour, in a theatre or densely crowded room three times per hour, the increased surface with proportionate boiler power &c., makes the first cost very heavy, but whatever the cost may be, the consideration of health and comfort should receive the first consideration.

Radiators should be placed near the outer walls, underneath windows, or in such other positions where they will be most efficient in checking currents of cold air, or distributing the warmed air, they should be provided with valves to regulate or shut off the heat, also with air taps, air pipes, or automatic air valves.

The mains leading to radiators should have a free circulation, avoiding square elbows, &c.

Connections to radiators should be proportioned to the amount of heating surface as follows:—

Radiators up to 50 ft. super require 1 in. connections.
From 50 to 150 ,, ,, ,, 1¼ ,, ,,
,, 150 to 250 ,, ,, ,, 1½ ,, ,,

If the radiator is some distance from the main pipes the branches leading to the radiator connections should be the next size larger, for instance, if a radiator with 50 ft. super is placed 20 ft. from the main pipes, the branch flow and return from mains to radiator should be 1¼ in. but where the radiators are close to the main pipes, the branches, valves and connections as given above will be found suitable.

CHAPTER XIX.

WASTE OF FUEL.

If the items coming under this heading could be tabulated in some concise form they would present some startling figures. This remark applies with equal force to almost every variety of purpose to which our fuel is applied—from boiling a drop of water in an ordinary kettle or saucepan to the generation of steam in the monstre boilers used in some of our large factories; from cooking a joint of meat in the kitchen range to the melting of iron and other ores in our huge furnaces.

In the appliances for heating, cooking, drying, generation of steam, motive-power, transmission of heat, &c., we find waste and extravagance that are simply alarming. We have vast coalfields that have contributed not a little to the wealth and prosperity of our nation. But our coal supply will not last for ever, and the question arises, are we not morally responsible for this reckless waste? If our mines were suddenly exhausted there would be a rude awakening, and it would be a national calamity; but if the output of our collieries were reduced by one-half it would probably be a blessing in disguise, for it would arouse us from a state of apathy, and create in a double sense a *burning* question.

Every ton of coal recklessly wasted is a loss to the nation just as much as if it were sunk to the bottom of the sea. A good deal has been done in the way of fuel-saving appliances, smoke abatement, &c., during the last few years. The following are a few examples out of many that have come under my own knowledge. Many of our notions are still antiquated, and we require some startling revelations to awaken us from our lethargy:

1. The proprietor of some blast-furnaces where a number of large boilers are constantly in use states that the improvements carried out in his works within the last few years have resulted in the saving of a ton of slack per hour.

2. In another factory an improved system of drying the goods by hot water (patented by the writer) instead of with flues, showed a clear saving for one drying room of about 12 tons of slack per week, besides which the goods were dried in half the time previously occupied.

3. The covering of three "Lancashire" steam-boilers and the steam-pipes to the engines, &c., saved from 8 to 10 tons of slack per week in one factory, and proved a good investment for the money expended.

4. The writer was consulted by a borough surveyor and other members of a committee respecting the heating of water for a number of public baths, the system previously adopted being from powerful steam boilers. Suggestions were made (one of which was to substitute a hot-water circulating boiler in the place of the steam-boilers) and adopted. The following is a copy of the report of the Committee as published in the local paper some time afterwards:—"The Committee had pleasure "in reporting that the alterations in the heating of the "baths had proved very satisfactory, and the great saving "anticipated in the Committee's report 16 months ago "had been effected. The slack consumed for the month "was 4 tons 7½ cwt. at a cost of £1, and the number of "baths taken was 395, being an increase of 118 compared "with the corresponding month of last year. This gave "an average receipt of 5d. per bath, whilst the slack cost "a fraction over ½d. The first year the heating of the "baths cost 11½d. each, the second year 11¼d., the third

"year 9½d., and the fourth year 8½d., or an average of a "little over 10d. per bath for four years; and the "average receipts during the same period were 4¾d. per "bath, showing a loss of 5¼d. for every private bath taken "during the four years, whereas under the altered system "there was a profit of 4¼d. for every bath taken. There "was, therefore, a clear saving to the ratepayers of 9½d., "and as to the increased comfort, ladies and gentlemen "alike expressed their gratification with the change."

Now let us focus these remarks, and bring them to bear on the subject under consideration. You may frequently see at some of our railway stations an immense fire in an open grate, with imminent risk of setting fire to the building, three-fourths of the heat escaping up the chimney, while the same amount of fuel properly utilised would heat the waiting-rooms, refreshment rooms, and other offices combined.

The ordinary fires in our dwelling-houses are equally extravagant. It has often struck me as a strange notion that we should sit warmly clothed in a room at 60° to 70° the whole evening, and then retire to a bedroom with a temperature fully 20° lower, and divest ourselves of our clothing; yet from force of habit it appears the proper thing; but who shall say how many weakly children, or adults of delicate constitution have taken chills that have proved fatal by these sudden and extreme changes.

On this important subject Dr. B. W. Richardson says, "It is always a matter of great moment to maintain an equable temperature in the bedroom. A bedroom, the air of which is subject to great and frequent and rapid changes of temperature, is often a trap for danger. To persons who are in the prime of life, and who are in robust health, this danger is less pronounced; but to the young and the feeble, it is a most serious danger. It is very dangerous for aged people to sleep in a room that is easily lowered in warmth.

"When the great waves of cold come on in these islands, in the winter season, our old people begin to drop off with a rapidity that is perfectly startling. We take up the list of deaths published in the *Times* during these seasons, and the most marked of facts is the number of deceased aged persons. It is like an epidemic of death by old age. The public mind accepts this record as indicative of a general change of external conditions, and of a mortality, therefore, that is necessary as a result of that change. I would not myself dispute that there is a line of truth and sound common sense and common observation in this view; but when we descend from the general to the particular, we find that much of the mortality seen in such excess among the aged is induced by mistakes on the subject of warmth in the bedroom.

"The fatal event comes about in this way. The room in which the enfeebled person has been sitting before going to bed has been warmed probably up to summer heat; a light meal has been taken before retiring to rest, and then the bedroom is entered. The bedroom, perchance, has no fire in it, or, if a fire be lighted, provision is not made for keeping it alight more than an hour or two. The result is that, in the early part of the morning, from three to four o'clock, when the temperature of the air in all parts is lowest, the glow from the fire or stove which should warm the room has ceased, and the room is cold to an extreme degree.

"The condition of the body itself is, at this very time, unfavourable for meeting any emergency. In the period between midnight and six in the morning the animal vital processes are at their lowest ebb. It is in these hours that those who are enfeebled from any cause most frequently die. We physicians often consider these hours as critical, and forewarn anxious friends in respect to them. From time immemorial those who have been accustomed to wait

Although the comparisons here given are not favourable to the use of Steam, there are cases in which Steam may be adopted with advantage, suppose for instance a Steam Boiler is in daily use for motive power, cooking and other purposes, and a small quantity of hot water is occasionally required for domestic purposes, it may not be convenient or economic to put in a hot water circulating Boiler, but whenever there is a constant or frequent demand for hot water, and only occasional or intermittent use for steam, a hot water circulating system will be found the cheapest and the best.

The Illustration Fig. 89 facing page 186 has been specially prepared, and shews what in my opinion is the best system for giving a constant supply of hot water to the various parts of an extensive Building. It represents a ground Plan of the Workhouse Buildings at Llanelly. The Architect W. Griffiths, Esq. has kindly given his consent for its reproduction in this Pamphlet, the scale is $\frac{1}{32}$ of an inch to the foot.

The Plant is used not only for supplying hot water to the various baths, lavatories, &c., but also for heating the ground and first floors of one block of the buildings. The Apparatus was designed and carried out by the writer.

The Boiler has a good margin of power for future extensions should they be required, and the approximate quantities of the materials used are here given.

Boiler "Trentham" 8ft. long by 4ft. diameter with 4 cross tubes.

Circulating Cylinder 9ft. long by 3ft. diameter.

40ft. of 4in. mains (cast iron) from Boiler to Cylinder.
640ft. of 3in. Cast Main Pipes.
1100ft. of 2in. Cast Main Pipes.
800ft. of 2in. Cast Pipes for heating portions of Buildings.
120ft. of 2in. Cast Pipes for heating laundry drying room.
200ft. of 1¼in. Wrought Galvanized Tube to baths, lavatories, &c.

300ft. of 1in. Wrought galvanized tube to baths, lavatories, &c.
14 Valves for cutting off the various blocks.
20 Draw-off cocks for Lavatories.
10 Draw-off cocks for Baths.

I have no hesitation in saying that if a Steam Boiler and plant had been put in, the first cost would have been double, and the perpetual cost of fuel at least 50 °/₀ more than is required with this apparatus.

I have carried out similar plants on a more extensive scale than this, where the buildings have been irregular and detached; my motive for selecting and illustrating these was that the Buildings were more symmetrical, and suited the space at my disposal better than the plans of others, and thus enabled me to adopt a somewhat larger scale than I could with buildings spreading over two or three times the area.

What are the advantages of this system? I will mention some of them.

1. The first cost is lower than that of a steam plant.
2. The fuel consumption is much less.
3. No risk of explosion.
4. No skilled attendant required.
5. Boiler and cylinder will run for one, two, or three years without cleaning out.
6. Hot water can be obtained a few minutes after starting the fire.
7. Hot water immediately the taps are opened, thus avoiding waste of water.
8. The fire may be banked up so that hot water may be had during the night or in the early morning.
9. Less risk, less danger, less wear and tear.
10. Alterations or extensions are more easily effected.

I will conclude this article by giving a few hints as to the principle points that should be observed in carrying out this class of work—first as to the best form of Boiler.

A self-contained Boiler is preferable, with mudlids or plugs to facilitate cleaning out the deposit.

Boilers set in brickwork are difficult to clean out, hence more likely to deteriorate.

For a head of water over 20ft. a boiler circular in form, and one in which the water space comes below the level of the fire bars is best, such as the " Titan " " Trentham," &c., this reduces the liability to damage in case of excessive sediment.

For heavy and constant work duplicate Boilers should be provided.

Main pipes between boiler and cylinder, also the mains to the various blocks should be provided with screw down valves in flow and return pipes.

An Expansion pipe or safety valve should be fixed on boiler, the circulating Cylinder, or hot water Tank should have a large manlid to facilitate cleaning.

All the mains and the circulating pipes, if cast iron should be coated inside, and if wrought iron should be galvanized, they should have a complete circuit (flow and return) carried as near as possible to all the draw-off cocks.

The longer the length of pipe, the greater should be the area. See table 10 page 116.

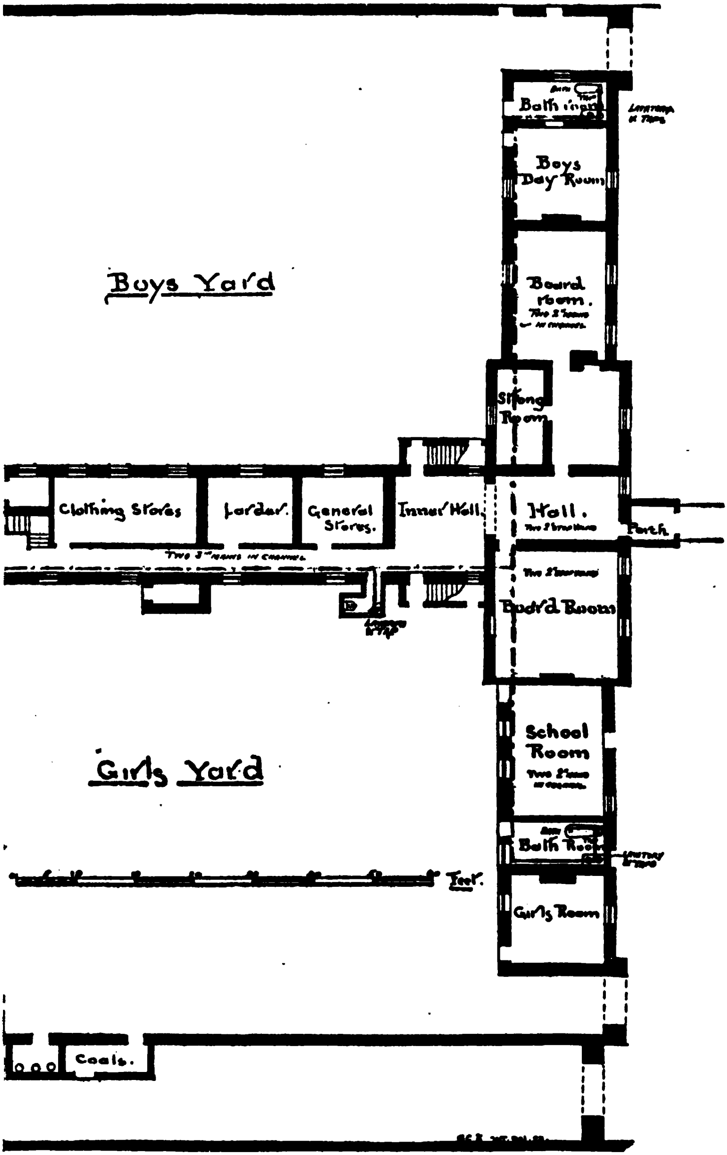
Cold water cistern should be clear above the highest circulating pipes and draw-off cocks.

Supply pipe from cistern to Boiler should be of ample size to replace the water as fast as it is withdrawn.

Service pipe to the cold water cistern, and the ball cock inside the cistern should be of sufficient size to maintain an ample supply.

Avoid pipes of small inside diameter, square elbows and sharp bends, &c.

Where there are several detached blocks of buildings especially if they are widely separated from each other, a separate and complete system for each block may be adopted.


Bath Room
Lavatory & Taps
Boys Day Room
Board room.
Boys Yard
Strong Room
Clothing Stores
Larder.
General Stores.
Inner Hall.
Hall.
Porch
Two 3" Mains in Channel
Board Room
School Room
Girls Yard
Bath Room
Lavatory & Taps
Feet.
Girls Room
Coals.

CHAPTER XXI.

BATH-APPARATUS.

The subject so far under consideration has been the heating of buildings by means of hot water. In the heating and storing of hot water for bathing, washing, or other domestic purposes the heat is conveyed and the circulation caused by the same motive-power, but the varying conditions, the *causes*, and the *results of failure* are more serious in the latter, and should, therefore, be carefully noted.

1. The boiler is small, and often subject to intense heat.

2. The small diameter of the pipes causes increased friction, and if in exposed positions they are liable to get frozen.

3. The action of the heat on water as it evaporates causes saline deposits (incrustation), and if allowed to accumulate the boiler may be overheated and cracked, or the pipes choked so as to prevent circulation, and thus cause an explosion.

4. Lead pipes are frequently used; they are not so quickly affected by corrosion, but are liable to sag from weight or expansion and cause the apparatus to get air-locked.

5. Wrought galvanized tubes are stronger and more suitable. Black tubes (*i.e.*, not galvanized) corrode very quickly, and should never be used.

6. The circulating pipes, whether of lead or iron, hould not be less than 1¼-inch, if a powerful boiler they should be 1½-inch or 2-inch.

7. The storage tank or cylinder (whichever is used) and the boiler, should in all cases be provided with manhole and cover so that they may be periodically cleaned.

8. A safety-valve should be attached to the boiler by a short independent pipe (not less than 1-inch) and should not be fixed to the circulating pipes.

9. If lead pipes are used the pipes passing through flues or brickwork should be of wrought galvanized iron, and then connected to the lead with brass unions.

10. When two lead pipes are joined they should be connected by a wiped (not soldered) joint.

11. The surface of boiler exposed to the flame must depend on the amount of work required.

12. If a leakage, however slight, occurs at or near the boiler, it should be stopped at once, as the moisture and damp thus generated are very destructive to boiler, pipes, ovens, &c.

There are two systems in common use:—

1. **The tank system.**
2. **The cylinder system.**

The latter is more modern, and considered by some people to be a decided improvement on the tank system. I shall endeavour to point out the advantages of each, and must leave it to the judgment of those about to fix to take all local circumstances into their consideration, and decide which will best meet their requirements. If I venture my advice I would say, "Do not adopt this system because your father did, or that because some other person did, but adopt the one calculated to give the maximum results with the minimum of risk, care, and attention."

One sometimes meets with a boiler of large dimensions, capable of holding 20 to 40 gallons, fixed at the back of range, having a cold-water supply pipe connected near the bottom of the boiler, which is supplied from a cistern a little above the boiler, the cistern being provided with a ball-cock. A draw-off pipe is connected near the centre of boiler with one or more hot-water taps, but without either circulating pipes, or tank, or cylinder, the hot water being stored in the boiler.

This is a very primitive arrangement, and cannot be recommended; it is wasteful in time and fuel, and if the greater portion of the boiler were exposed to the action of the fire, it would be so much above its work that steam would be generated and blow through the escape-pipe, a considerable thumping noise would be caused by concussion, resulting in inconvenience, and not unaccompanied by danger from explosion.

The storage tank may be square, oblong, round, or any other shape. It should be a closed vessel, with man-hole and cover for facility of cleaning. Square or oblong tanks occupy less space, and are lower in price (in proportion to their capacity) than cylindrical; the latter are the best shape for resisting pressure, and may be fixed horizontal or vertical. They are generally adopted where there is a considerable head or pressure of water; hence the appelation of the term cylinder system, this form of vessel being generally used when fixed in the kitchen or near the range.

In large towns or cities, especially where the Corporation or governing authorities own the waterworks and have the water-supply under their control, stringent bye-laws are frequently adopted and enforced.

The Corporation of Birmingham made and adopted bye-laws in 1887 for "preventing waste, misuse, undue consumption, or the contamination of water." These bye-laws were sanctioned and allowed by the Local Government Board in May, 1887. They apply to the cold-water and hot-water supply, service pipes, stop-cocks, guard-boxes, joints, closets, urinals, baths, cisterns, cylinders, &c.; they specify the minimum weight of lead pipes, bib-taps, ball-cocks, &c. The following is a copy of the portion of these bye-laws relating specially to bath apparatus:—

"A person who shall fix or fit on any premises a bath or hot-water apparatus that may be intended to be used for receiving the water of the corporation shall comply with the following regulations, that is to say :—

"1. For the supply of baths a cold-water cistern, containing at least 60 gallons, must be provided."

"2. The same 60-gallon cistern may be used to supply a hot-water apparatus, but the cold-water supply to the bath must in that case be connected to the cistern at a point not below one-half the depth of the cistern."

"3. The feed cistern tc the hot-water circulating cistern or apparatus must be fixed at a lower level than the bottom of the said cold-water cistern. Or when the hot-water apparatus is carried out upon the cylinder system, the bottom of the aforesaid 60-gallon cold-water cistern may be connected directly to the hot-water cylinder, but all the hot-water draw-off pipes must be connected at or above the top of the hot-water cylinder."

"4. All cylinders, if not of copper, must be of wrought-iron plates, not less than ⅛-inch thick, galvanized, and must contain at least 50 gallons."

"5. Hot-water circulating cisterns not under pressure must be of at least one-sixteenth wrought-iron sheet galvanized."

"6. Circulating or supply pipes for hot water may be either of lead, iron, or copper. If of iron they must be 'steam tubes' galvanized."

"7. Water to baths must not be supplied through an emptying pipe, but by a separate pipe not less than 6 inches above the bottom of the bath or over the top of the bath."

THE TANK SYSTEM.

This system will be understood by a reference to illustration No. 90 and the following description. The principal features are :—

Boiler.
Circulating-pipes. the course of the Water being indicated by arrows.
Hot-water or storage tank.
Supply-cistern (cold water) and ball-cock.
Feed-cistern (cold water) and ball-cock.
Supply-pipe (cold water) from main.
Overflow, or warning pipe.

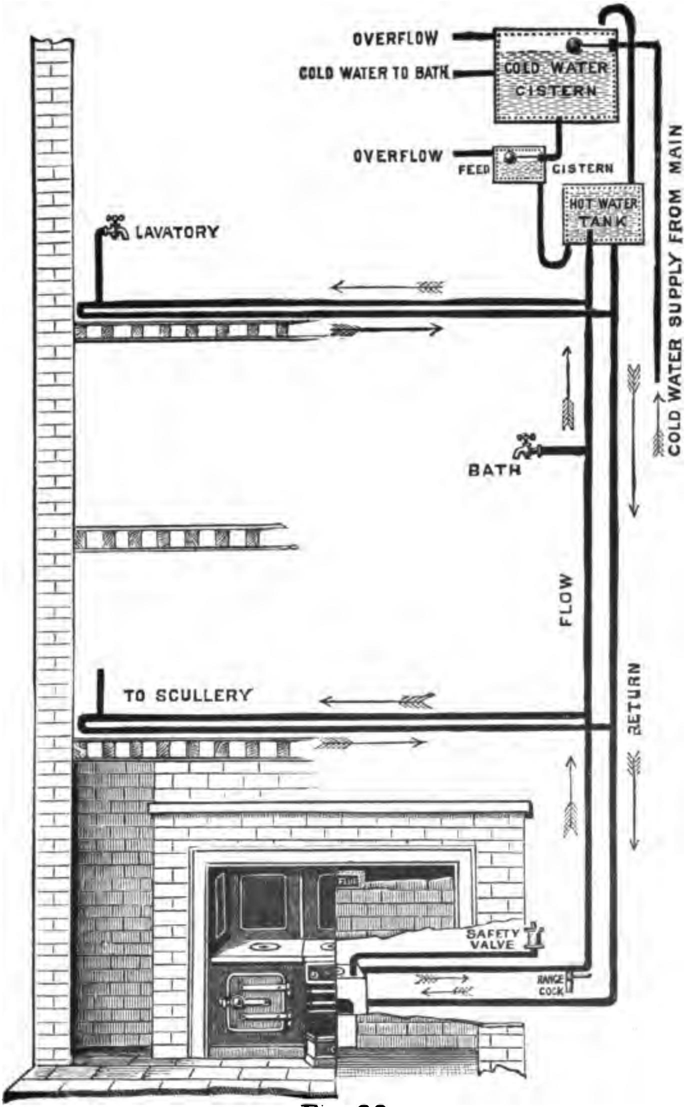


Fig. 90.

BATH APPARATUS—TANK SYSTEM.

The description and illustration (Fig. 90) are in conformity with the bye-laws already referred to; in other towns, where they have no such bye-laws, one cold-water cistern only is used, which serves the purpose of supply and feed cistern. When this is the case it is desirable that the cistern should contain at least 50 gallons, and if the water supply is intermittent, and not constant, a much larger size may be advantageously adopted. Sometimes the cold water to bath is taken direct from the main; this is not to be recommended, as the water may be cut off just at the moment when it is required for a bath.

Boiler.—The size, shape, and position of boiler depend on the make of the range in which it has to be fixed; sometimes it is fixed at the side, but generally at the back of the fire. The following illustrations show a few only of the forms most commonly used. Other shapes are made in great variety. In some cases special designs are made to suit the requirements of the range.

The boilers commanding the largest sale are the following:—

Bath-boiler, with arched flue (Fig. 91).
Bevil-front bath-boiler (Fig. 92).
Boot boiler (Fig. 93).

It is of the utmost importance that all bath and range boilers should be provided with manhole and cover, which should be removed, and the boiler cleaned and scurfed periodically, especially when the water is known to leave a good deal of deposit.

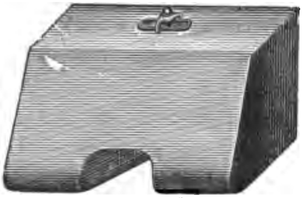


Fig. 91.

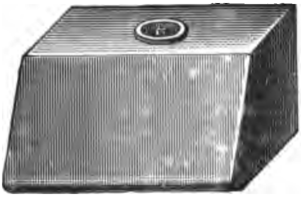


Fig. 92.

In some parts of America a single coil of strong wrought tube, about $\frac{5}{8}$ inch bore, is passed through the back of their self-contained ranges, crossing the front near the bars, and returned to the back of range, thus forming the three sides of a square, and this short length of tube constitutes the boiler, the ends being connected to a small circulating cylinder, which is made specially strong to withstand the pressure from the mains. If this system were adopted with the water to be found in many parts of England the boiler would, owing to its small capacity, be choked, and burned through in a few months.

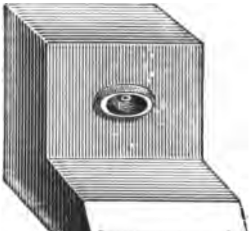


Fig. 93.

In some parts of Yorkshire a chemical action is exerted by the acids or alkalies contained in the water, which is very prejudical to lead or iron, and eats away the boiler and pipes in a remarkable manner. To resist this action copper boilers are used and lead pipes lined with tin, the copper and the tin being impervious to the chemical action referred to.

The circulating pipes may be connected either on the side, back, or top of the boiler, as most convenient. The flow should be kept as close to the top as possible and the return about two inches from the bottom; they should then be carried with as few bends as possible direct to the hot-water tank, avoiding square elbows, especially in flow. The mouth of return should be 1 inch to 2 inches above bottom of tank, and the flow near (or above) the centre of tank. Hot water services may be taken off the flow-pipe at any point between the boiler and tank for supplying bath, lavatory, scullery, &c. When these fixtures are some distance away from the rising pipes, a double row of pipes should be put to keep up a circulation, otherwise a quantity of cold water will have to be drawn off every time the tap is opened before the hot water commences to flow. A hot-water cock placed by the side of range is convenient for use, and for emptying the apparatus when necessary.

It is very desirable that the flow from boiler to tank and the return from tank to boiler should be at least 1¼ inch. This statement may be challenged even by practical people. My reason for this assertion is that I have known instances where 1-inch pipes have been quite choked up by incrustation with six months use. Steam has been generated which forced a passage up the return pipe with a noise, concussion, and vibration that shook the building, apart from the risk of damage to property or loss of life by explosion. I have had to take out 1-inch and even ¾-inch pipes (recently fixed by local plumbers) and substitute 1¼-inch in a number of instances during the last two years.

When the tank or cistern are fixed in the roof, they, and the pipes leading to them, should be protected (with non-conducting materials) from the effects of frost. If the cold-water main-pipe is carried up alongside the circulating pipes it may be sufficiently protected while the apparatus is working, but, as stoppages may occur from various causes, or the house may become void during frosty weather, these are contingencies that should be guarded against. If a spare room can be found for them on the top floor, instead of in the roof, the risk of damage by frost is minimized, and, by casing the tank so as to form a cupboard, the heat may be utilized for airing linen, &c., which will be found a very convenient fixture.

The cold-water cistern is frequently connected to the storage-tank with a U pipe, one end underneath each; sometimes they are connected to the sides instead. One weak feature of this arrangement (especially if storage-tank is small) is that, when a quantity of hot water is required, immediately the hot water commences to run the cold water rushes into the hot tank, and lowers the temperature before it is nearly emptied. This may be obviated by connecting the cold-water cistern to the return-pipe as far as convenient from the tank. In any case, a syphon or U pipe should be used to prevent the hot water backing up into cold-water cistern. Or this may be effected by connecting the sides of the two cisterns with a straight pipe in which a check-valve is fixed which opens and closes automatically when water is withdrawn.

An overflow not less then 1¼-inch should be fixed near the top of cistern and the ball-cock adjusted to allow 2 or 3 inches between overflow and the water-level. The end of overflow-pipe should be carried over a rain-water gutter or an open gulley-grate, where it can be seen; it should not under any circumstances be connected with a closed drain-pipe, or the water may become contaminated with sewer-gas.

Safety-valves are not always attached; they are, nevertheless, desirable; anything that will minimize risks should be worth the additional cost that may be necessary. If fixed on the circulating pipes it may get deranged by concussion if a tap is closed suddenly, or the pipe may get choked between the boiler and the valve, when it would be a *danger* instead of a *safety*-valve. It should be attached to the boiler by an independent pipe about 1-inch diameter.

THE CYLINDER SYSTEM

possesses important advantages over the tank system, although it is not without its own weak features, which I will simply mention, so that they may be guarded against:—

1. **The supply-cistern** and pipes are more exposed to the action of frost, having no heat near them.

2. The capacity of cylinders most commonly fixed are only about one-half to two-thirds that of storage-tank.

3. Cylinder liable to collapse, viz., when steam is geneated, causing a rumbling noise; hot water is drawn and cold water suddenly introduced, which condenses the steam, and forms a vacuum; if the cylinder is too light the sides collapse.

4. The heat from the range in most cases makes the kitchen uncomfortably hot; the addition of cylinder makes it still more uncomfortable.

The weak points above mentioned are not of vital importance; they may be avoided or minimized; and, if the apparatus is properly fixed, there are redeeming features that more than outweigh them.

Advantages claimed for the Cylinder System.

1. Circulation will continue if water-supply temporarily fails; the failure of hot-water cocks to run is a warning to close boiler damper immediately, or withdraw the fire.

2. The short circulating pipes between boiler and cylinder reduce the risk of stoppage from incrustation.

3. The two points above mentioned minimize the liability of explosion.

4. Hot water can be procured quicker and at a higher temperature.

5. The hottest water is withdrawn before the temperature is lowered.

The principal difference between the systems is that the hot-water *tank* is placed above the rising pipes, and the *cylinder* below them. The causes of failure, and the remarks and suggestions given on the tank system will apply generally to the cylinder system also.

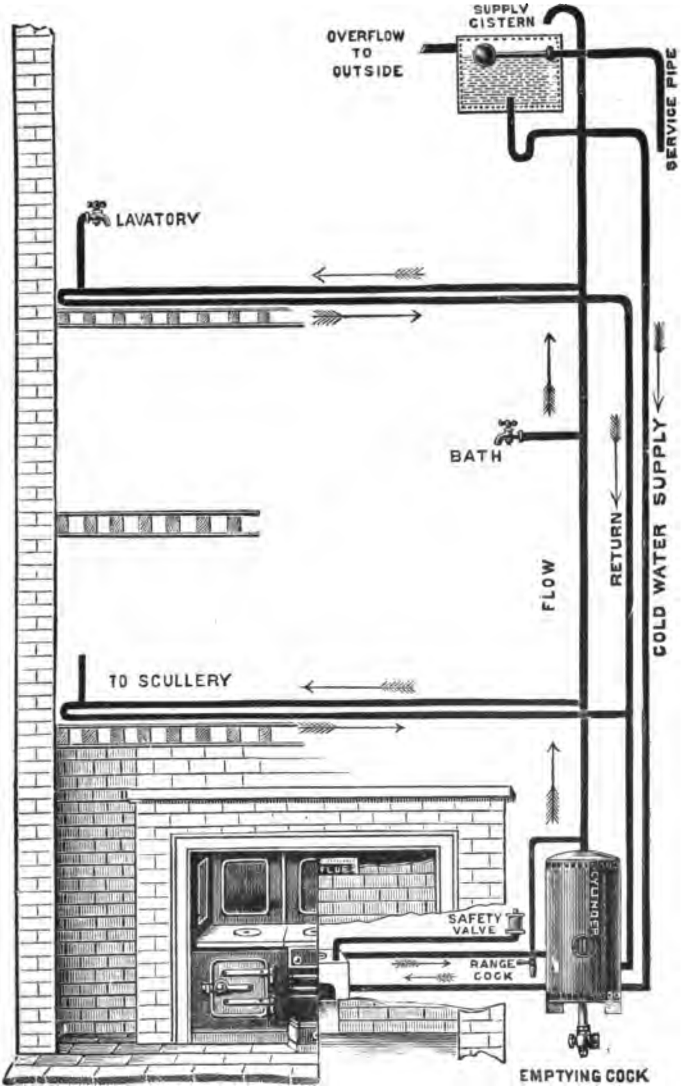


Fig. 94.

BATH APPARATUS—CYLINDER SYSTEM.

Reference to the illustration No. 94, and the instructions for fixing, will, I trust, make this system tolerably clear.

INSTRUCTIONS FOR FIXING.

1. **Connect flow-pipe** (not less than 1¼-inch) at top of boiler and about 8 inches to 12 inches up cylinder.

2. Connect return-pipe at or near the bottom of cylinder and boiler.

3. Provide emptying-cock underneath cylinder, the key of which should be removed so that it cannot be used except when apparatus requires to be flushed, emptied, or cleansed.

4. Connect rising (flow) pipe not less than 1 inch to top of cylinder, and carry through roof or over supply cistern, taking off branches for bath, lavatory, &c., as required, connect on its return to cylinder or to return-pipe between cylinder and boiler. Sometimes a rising pipe is used without a return. It is a very questionable saving, and cannot be recommended.

5. Fix supply-cistern in roof, or upper room of house, and supply by ball-cock from cold-water main.

6. Connect overflow-pipe as described under "Tank System."

7. Carry supply-pipe from cold-water cistern into bottom of cylinder or return-pipe near boiler.

8. All draw-off cocks should be connected to rising pipe above cylinder, so that the latter cannot be emptied in work.

9. Attach safety-valve to boiler by an independent pipe.

10. Iron cylinders galvanized are frequently used. For first-class work copper cylinders tinned inside are better.

Providing the boiler is sufficiently powerful, either system may be extended *ad libitum* for warming the various portions of the house with coils, &c., or for towel-warmers and various other contrivances. I have in several instances heated from 500 to 1,000 feet of pipes from the kitchen boiler, in addition to large hot-water supply for baths, scullery, &c. In cases of this kind the boiler must be proportioned to the amount of work required.

CHAPTER XXII.

BATH APPARATUS BY INDIRECT OR BORROWED HEAT.

The foregoing articles describe the methods usually adopted with the tank system and cylinder system when connected with the ordinary cooking range: the following is a description of a system the principle of which is not absolutely new, but its application to ranges may be considered unique. It is a combination of high-pressure and low-pressure heating, and possesses some important advantages over the systems already described. The high-pressure portion consists of two coils, one of which is fixed instead of, and in the position usually occupied by, the bath boiler at the back of the range; the other coil is placed inside a close tank or circulating cylinder, both coils being connected so as to form a complete circulating system of $\frac{7}{8}$-inch bore high-pressure tube, screwed right and left, with expansion tube, cap for filling, &c., as described under "High-pressure Heating," Chaps. I and II. The water in the circulating cylinder is distinct from, and cannot mix with, the water contained in the high-pressure tubes; the circulating cylinder may thus be emptied of water without in any way affecting the boiler, as the circulation will still continue in the high-pressure tubes, which are hermetically sealed. In other respects, the circulating pipes from the cylinder to bath, the cold-water cistern, supply-pipe, draw-off cocks, &c., are connected as described and illustrated (Fig. 94) under the cylinder system. The water in the cylinder is heated by its contact with the coil, *i.e.*, by indirect or borrowed heat. This apparatus has been working for four years, heating drawing-room, bath-room, and schoolroom, and supplies hot water for bath, lavatory, scullery, &c., with very satisfactory results, and may be inspected by anyone desirous of doing so. The high-pressure portion requires about one pint of water after four months daily use.

The principal advantages are as under:—

1. The boiler cannot get foul, as the water is not changed.

2. It cannot, therefore, burn or crack from accumulation of sediment.

3. There is no necessity to pull the range to pieces for periodical cleaning of boiler and pipes.

4. Any accumulation in the cylinder is easily removed by taking off the mud-lid.

5. The risk of explosion is minimized.

It may be here mentioned that this class of work should not be entrusted to inexperienced hands: for, whilst it is safer if properly fixed than the ordinary bath apparatus, it would, if improperly fixed, be more dangerous.

The utilization of the range fire for the double service of cooking and supplying hot water may be convenient, but it is not economic. All cooking ranges are fuel devourers, and when a hot-water boiler is attached, the fuel consumption is always much heavier. For cooking purposes only, gas cookers are the best, quickest, cleanest and cheapest, and for hot water supply a small independent boiler, which may be fixed by the side of the cooking range, or in the basement, or any other convenient place, will give better results with half the fuel commonly used in the range. The only argument that can be used in favor of range boilers is that it saves the trouble of keeping a second fire going. Now what are the arguments against it?

1. The surface of boiler exposed to the flame is small.

2. It takes an extravagant quantity of fuel to do a small amount of work.

3. The draught under the boiler is keen and impinges ectly on the part where the sediment is deposited.

4. The life of the boiler is consequently short, frequently requiring renewal once a year.

5. When cleaned or scurfed, the cooking operations are also suspended.

6. When a new boiler is required, it necessitates a heavier cost in brickwork than the price of the boiler, and causes much work and inconvenience from the consequent dust, dirt, brickdust and soot.

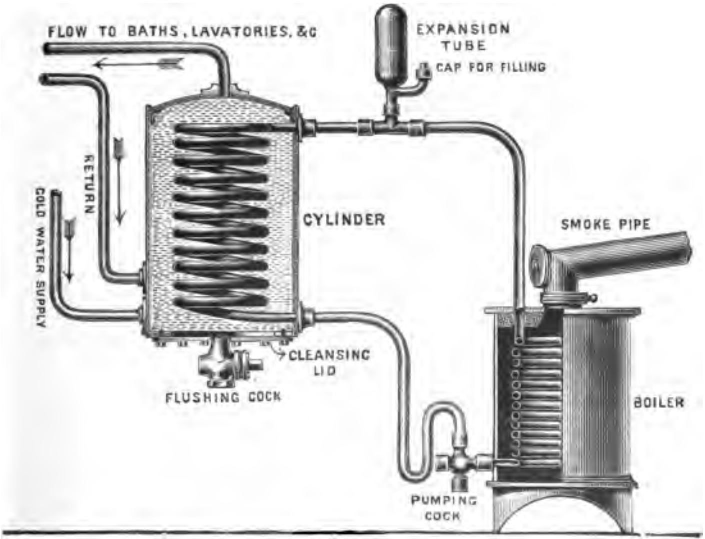


Fig. 95.
HIGH & LOW PRESSURE (COMBINED) HOT WATER SUPPLY.

The very best system that could possibly be introduced for domestic hot water supply would be (in my opinion) a small self-contained high-pressure boiler independent of the range, and the water heated by indirect heat as herein described, and as illustrated in Fig. 95, the first cost would be a little heavier, but the cost in repairs or renewals would be infinitesimal, and the results and convenience would far more than compensate for the small extra cost, I hope shortly to introduce an apparatus of this description suitable for dwelling-houses, &c.

CHAPTER XXIII.

LAUNDRY DRYING ROOMS, TURKISH BATHS, AND SWIMMING BATHS

Laundry drying rooms are heated in various ways, by hot-air flues, hot-air pipes, steam pipes, and by hot water. The writer has tried all three systems, and for temperatures up to 120° Faht. unhesitatingly recommends hot-water as the simplest, cleanest, and most economic; for temperatures over 120°, steam, or high-pressure water are more suitable.

If a steam boiler is already fixed conveniently at hand, it would reduce the cost and be more convenient to heat by live steam direct under pressure, but if a complete apparatus is required, hot water is undoubtedly the best and the cheapest.

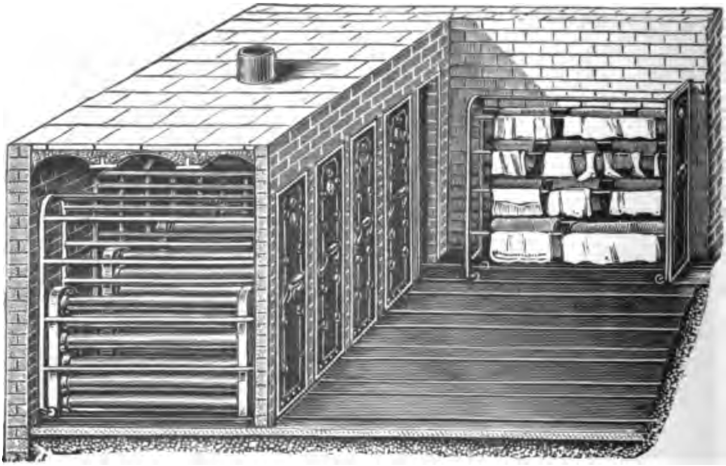


Fig. 96.
LAUNDRY DRYING ROOM.

When heated with pipes (hot-water or steam) they are frequently fixed underneath the floor level, and covered with open gratings. The apparatus illustrated Fig. 96 was designed and erected by the writer; the pipes being above the floor level are easily accessible, and work more economically than when under-ground; the boiler also heats the water in a close tank (about 200 gallons). The temperature of this stove when drying wet clothes averages 90° to 100°, and when airing the clothes from 120° to 130°; and it gives an abundant supply of water near boiling point for wash-house purposes.

For supplying hot water for hydropathic establishments or other public buildings, washhouses, laundries, etc., the following points should be observed:—

1. A boiler of ample power, with a good water-space, and mud-lids conveniently fixed for cleaning the inside of boiler.
2. A self-contained boiler is more convenient for cleaning than one buried in brickwork.
3. All circulating pipes, and the hot-water tank should be galvanized.
4. The drying-horses should be made of galvanized iron.
5. Drying stove should have a ventilating shaft on top with damper or other means of regulating the exit of air.
6. Thorough ventilation is quite as essential as a high temperature.

TURKISH BATHS.

The temperatures necessary for Turkish baths (180° to 240°) are too great for low-pressure heating apparatus. They are frequently heated by flues in the walls of the building, which are hollow and specially constructed for the purpose. The same results may, however, be attained by high-pressure live steam, or by hot water on the high-pressure system. As this work is generally done by specialists, it is not necessary to give full description of the various systems employed.

SWIMMING BATHS.

For heating large bodies of water, such as swimming baths, or for circulating water around large gas-holders to prevent freezing, low-pressure hot-water circulating boilers are best. Swimming baths are frequently heated by steam, either by passing steam pipes through the water, or by blowing live steam into the water. Both systems are objectionable and costly, both as regards the cost of plant and the perpetual cost of fuel, &c.

The simplest method, and the most economic, is to fix a powerful circulating boiler below the level of the bath, and circulate direct through galvanized pipes from the boiler to the bath. The flow pipe should be connected at the shallow end and near the bottom of the bath, returning from the deep end, and from the bottom of bath. If the bath is very large (say 40,000 gallons or upwards), two or more flow and return-pipes may be used with advantage so as to keep the temperature of the water nearly uniform. The temperature of the water in the flow-pipe rarely exceeds 90° to 100°, and the time occupied in raising the water to the required temperature 75° to 80° will depend on the power of the boiler, and the quantity of water contained in the bath, and may vary from four to twelve hours.

To give the required temperature for swimming baths (75° to 80°) the following table gives the approximate power of boilers suitable. The table must be taken as approximate only, as the heating powers of many boilers are over-estimated: the superficial heating-surface would be still less reliable, as the value of the surface varies considerably, according to the construction or design of the boiler.

TABLE 18.

Boiler power required for **Swimming Baths.**

CONTENTS OF BATH.	HEATING POWER OF BOILER, ACTUAL.	OR STEAM BOILER POWER·
Gallons.	Feet of 4in. Pipes.	Horse Power.
5.000	500	2
10,000	1,000	4
15,000	1.500	6
20,000	2,000	8
25,000	2,500	10
30,000	3,000	12
35,000	3.500	14
40,000	4,000	16
45,000	4 500	18
50,000	5,000	20

For each 1,000 gals. allow actual heating power = 100ft. of 4-in. pipes.

Boilers more powerful than those mentioned would raise the temperature in a less time, and would be more economic in fuel. If the bath contains over 40,000 gallons, it may be more convenient to use two boilers.

CHAPTER XXIV.

CONCLUSION.

Having described pretty fully the various systems of heating apparatus and bath apparatus generally adopted, I may state that I consider them far from perfect, and that the whole thing wants revolutionizing, especially the warming of dwelling houses and the supply of hot water. I will mention some of the principal objections, and state how they may be remedied. In the first place, kitchens, instead of being large, airy, and well-ventilated rooms, are often small, low, close, and stuffy. Secondly, many of the ranges are constructed to burn the greatest quantity of fuel, whilst giving the worst possible results. The cook may often get a good basting, with very questionable success as regards the cooking. How many ranges are constructed for close fires only, and in such a manner that every time the lid is removed to put on more fuel, or to boil a drop of water, the kitchen (which should be the cleanest room in the house) is defiled with smoke, soot, dust, and filth in a manner simply atrocious ? Most ranges are more or less dirty. A good deal of it may be attributed to the carelessness of servants, but in many cases the utmost care will not prevent it.

It is not always the fault of the range maker. It frequently happens that the fault lies with the bricklayer who sets it. The difficulty may be avoided by using self-contained ranges ; but many of these are so contracted in the flues that they will scarcely go a single week without getting blocked with soot and ashes.

What greater boon can one have in a house than a good bath apparatus, and an abundant supply of hot water always to hand ? Yet in how many cases these luxuries are a constant source of anxiety, trouble, and expense, and chiefly from causes which may readily be prevented—pipes being buried in a mass of brickwork, instead of being easily accessible; too small in area, and speedily filled with incrustation; too weak for the work required, and bursting and flooding the place; boiler man-lids leaking, taps getting out of order, &c. Am I exaggerating? I leave the householder who has passed through these experiences to answer.

Thirdly, what is the general opinion of the ordinary plumber? He is ridiculed by all the comic journals as a man to be dreaded in nearly every household. The work of the plumber is more important than that of almost any other branch of the building trade. His carelessness may propagate and foster malignant diseases that defy the skill of the medical man.

Why is he so dreaded? Because of the slovenly, slipshod, bungling, jerrymandering way in which this work is so often done—in a manner that is simply a disgrace to the British workman. If plumbers would take a more intelligent interest in their work we should have fewer complaints, and they would be less exposed to ridicule.

Heat is as essential to our being as light. Why should we have gas carried into every room in the house and confine the heat to one or two rooms only? It may not be worth the trouble and expense of pulling about every room in a house, newly finished and decorated, to put in artificial heat, but there is no reason why architects should not make provision (in every new house at least) for keeping the whole building thoroughly aired from basement to roof from one apparatus. The heat may be turned on and off in the various rooms just as easily as the light. I see no reason why every room in the house, including the kitchen, should not be thus warmed from a single fire in the basement, with no greater consumption of fuel than that ordinarily used in the kitchen range alone.

Inlet and **exit ventilators** should also be provided in connection with the heating, so that every room could be efficiently warmed, and ventilated through the roof: this question is worthy the serious attention of all architects, and I should be glad to show this system, in actual work, to any person interested in the subject.

And what about the cooking? For intermittent work as cooking, or boiling water, a gas cooking stove will do the work better, cheaper, and more expeditiously. The saving of labour in having no fires in the house, with the consequent accompaniments of coal dust, black lead, scouring and scrubbing, would often save the cost of a servant.

There is another point of still greater importance—the suffering and illness arising from coughs, colds, rheumatism, and sundry other ailments brought on by damp houses, cold rooms and passages would be mitigated, and apart from the increased comfort, the saving in doctors bills, etc., would more than compensate for any slight expense that might be incurred in a good apparatus. Some may say, "Oh! It sounds very well, but let me see a good fire." Well, there is a good deal of sentiment about it; we prefer to see a fire because we have been accustomed to it. We are content to sit in a church, schoolroom, or other public building, or in our own offices, without seeing a fire, and we do not miss it so long as we get the sensation of warmth; so in our homes, in a short time, we should not miss the fire, and it would not be difficult to furnish our fire-places with something more artistic and attractive than many of our fire-grates and their accessories.

A person with a strong constitution, in robust health can withstand extreme cold, whereas a change in moving from one room into another a few degrees lower in temperature, will cause great discomfort to the weakly or delicate. A gale of wind that would serve as a tonic to the strong, would bring suffering or death to the invalid.

When a lad, I often wondered how my father could tell before leaving his bedroom that the wind was blowing from the East. *I know now.*

How many thousands of people are to-day martyrs to Bronchitis, Asthma, and Rheumatism brought on by damp, cold and unhealthy rooms? The death rate throughout the whole of the kingdom is much higher than it should be, and in large cities or populous districts it is frequently double that of the rural districts. Good health is the greatest blessing that we can possess. Why should we permit this high rate of mortality? which does not by any means represent the sum total, for a high death rate bears with it a corresponding or relative increase in sickness and suffering also.

I hold that every room in every house from the peer to the peasant, and all the passages, corridors, staircases, &c. should be kept free from damp, and warmed to a temperature of not less than 50 Fah. with facilities for increasing the temperature of the living or general rooms to 60°. We should see a marked reduction in the death rate, and a corresponding diminution in cases of sickness. Again every house should be provided with conveniences for bathing. What! provide the artisan or labourer with the luxury of a bath? Yes. Why not? Surely the man who is engaged in the Ironworks, Mills, Mines, and Factories, stands more in need of a bath than the man who never soils his hands. Our Prisons, Workhouses and Asylums are provided with facilities for bathing. Why should we deny to the toilers who are the backbone and sinew of our commercial existence the privilege that is extended to criminals, paupers and lunatics? If the necessary conveniences cannot be obtained in the houses of the worker, they should be provided free of cost by the local Authority; it is true that in large towns baths are provided, but the price charged for their use is often prohibitive to those who need them most, and there are many towns where no such provision is made at all. If cleanliness is next to godliness, then the art of swimming should be taught to all the lads and girls in our elementary schools and thus form an essential part of their education.

We spend millions of pounds on unwieldy Ironclads, huge Military and Naval Armaments, Sanitation, free Education, Hospitals, Prisons, and Workhouses. Surely money spent in promoting health, cleanliness, and the prevention of sickness would prove a judicious, economic, and satisfactory expenditure.

I have met with persons who after a few months experience of a superficial nature, flattered themselves they knew all and everything about Hot Water Engineering. Well, after 20 years experience, during which time I have endeavoured to take an active and intelligent interest in this subject, I am just beginning to feel how little I know, and to recognize the extent of my own ignorance. I have told you a few things that I do know, but if I were to tell you the things I don't know, it would require an immense volume.

In treating on the various subjects under consideration, the writer has endeavoured to do so fairly, and without prejudice, giving as far as possible the advantages of each, without unduly depreciating any, and he trusts the suggestions may be helpful, and enable others to surmount obstacles and overcome some of the difficulties most commonly met with, always bearing in mind the maxim, "That which is worth doing at all is worth doing well."

TABLE 19.

Area of **Circles** in inches advancing by 8ths.

Dia. in inches	0in.	⅛in.	¼in.	⅜in.	½in.	⅝in.	¾in.	⅞in.	Dia. in inches.
0	·0	·0122	·0490	·1104	·1963	·3068	·4417	·6013	0
1	·7854	·9940	1·227	1·484	1·767	2·073	2·405	2.761	1
2	3·141	3·546	3·976	4·430	4·908	5·411	5·939	6·491	2
3	7·068	7·669	8·295	8·946	9·621	10·32	11·04	11·79	3
4	12·56	13·36	14·18	15·03	15·90	16·80	17·72	18·66	4
5	19·63	20·62	21·64	22·69	23·75	24·85	25·96	27·10	5
6	28·27	29·46	30·67	31·91	33·18	34·47	35·78	37·12	6
7	38·48	39·87	41·28	42·71	44·17	45·66	47·17	48·70	7
8	50·26	51·84	53·45	55·08	56·74	58·42	60·13	61·86	8
9	63·61	65·39	67·20	69·02	70·88	72·75	74·66	76·58	9
10	78·54	80·51	82·51	84·54	86·59	88·66	90·76	92·88	10
11	95·03	97·20	99·40	101·6	103·8	106·1	108·4	110·7	11
12	113·0	115·4	117·8	120·2	122·7	125·1	127·6	130·1	12
13	132·7	135·2	137·8	140·5	143·1	145·8	148·4	151·2	13
14	153·9	156·6	159·4	162·2	165·1	167·9	170·8	173·7	14
15	176·7	179·6	182·6	185·6	188·6	191·7	194·8	197·9	15
16	201·0	204·2	207·3	210·5	213·8	217·0	220·3	223·6	16
17	226·9	230·3	233·7	237·1	240·5	243·9	247·4	250·9	17
18	254·4	258·0	261·5	265·1	268·8	272·4	276·1	279·8	18
19	283·5	287·2	291·0	294·8	298·6	302·4	306·3	310·2	19
20	314·1	318·1	322·0	326·0	330·0	334·1	338·1	342·2	20
21	346·3	350·4	354·6	358·8	363·0	367·2	371·5	375·8	21
22	380·1	384·4	388·8	393·2	397·6	402·0	406·4	410·9	22
23	415·4	420·0	424·5	429·1	433·7	438·3	443·0	447·6	23
24	452·3	457·1	461·8	466·6	471·4	476·2	481·0	485·9	24
25	490·8	495·7	500·7	505·7	510·7	515·7	520·7	525·8	25
26	530·9	536·0	541·1	546·3	551·5	556·7	562·0	567·2	26
27	572·5	577·8	583·2	588·5	593·9	599·3	604·8	610·2	27
28	615·7	621·2	626·7	632·3	637·9	643·5	649·1	654·8	28
29	660·5	666·2	671·9	677·7	683·4	689·2	695·1	700·9	29
30	706·8	712·7	718·6	724·6	730·6	736·6	742·6	748·6	30
31	754·8	760·9	767·0	773·1	779·3	785·5	791·7	798·0	31
32	804·2	810·5	816·9	823·2	829·6	836·0	842·4	848·8	32
33	855·3	861·8	868·3	874·8	881·4	888·0	894·6	901·3	33
34	907·9	914·6	921·3	928·1	934·8	941·6	948·4	955·3	34
35	962·1	969·0	975·9	982·8	989·8	996·8	1003·8	1010·8	35
Dia. in ft.	0 in.	1½in.	3in.	4½in.	6in.	7½in.	9in.	10½	Dia. in ft.

Area of **Circles** in feet and inches.

TABLE 20.

Circumferences of **Circles** in inches advancing by 8ths.

Dia. in inches.	0in.	⅛in.	¼in.	⅜in.	½in.	⅝in.	¾in.	⅞in.	Dia. in inches.
	·0	·3927	·7854	1·178	1·570	1·963	2·356	2·748	0
1	3·141	3·534	3·927	4·319	4·712	5·105	5·497	5·890	1
2	6·281	6·675	7·068	7·461	7·854	8·246	8·639	9·032	2
3	9·424	9.817	10·21	10·60	10·99	11·38	11·78	12·17	3
4	12·56	12·95	13·35	13·74	14·13	14·52	14·92	15·31	4
5	15·70	16·10	16·49	16·88	17·27	17·67	18·06	18·45	5
6	18·84	19·24	19·63	20·02	20·42	20·81	21·20	21·59	6
7	21·99	22·38	22·77	23·16	23·56	23·95	24·34	24·74	7
8	25·13	25·52	25·91	26·31	26·70	27·09	27·48	27·88	8
9	28·27	28·66	29·05	29·45	29·84	30·23	30·63	31·02	9
10	31·41	31·80	32·20	32·59	32·98	33 37	33·77	34·16	10
11	34·55	34·95	25·34	35·73	36·12	36·52	36·91	37·30	11
12	37·69	38·09	38·48	38·87	39·27	39 66	40·05	40·44	12
13	40·84	41·23	41 62	42·01	42·41	42·80	43·19	43·58	13
14	43·98	44·37	44·76	45·16	45·55	45·94	46·33	46·73	14
15	47·12	47·51	47·90	48·30	48·69	49·08	49·48	49·87	15
16	50·26	50·05	51·05	51·44	51·83	52·12	52·62	53·01	16
17	53·40	53·79	54·19	54·58	54·97	55·27	55·76	56·15	17
18	56·54	56·94	57·33	57·72	58·11	58·51	58·90	59·29	18
19	59·69	60·08	60·47	60·86	61·26	61·65	62·04	62·43	19
20	62·83	63·22	63·61	64·01	64·40	64·79	65·18	65·58	20
21	65·97	66·36	66·75	67·15	67·54	67·93	68·32	68·72	21
22	69·11	69·50	69·90	70·29	70·68	71·07	71·47	71·86	22
23	72·25	72·64	73·04	73·43	73·82	74·22	74·61	75·00	23
24	75·39	75·79	76·18	76·57	76·96	77·36	77·75	78·14	24
25	78·54	78·93	79·32	79·71	80·10	80·50	80·89	81·28	25
26	81·68	82·07	82·46	82·85	83·25	83·64	84·03	84·43	26
27	84·82	85·21	85·60	86·00	86·39	86·78	87·17	87·57	27
28	87·96	88·35	88·75	89·14	89·53	89·92	90·32	90·71	28
29	91·10	91·49	91·89	92·28	92·67	93·06	93·46	93·85	29
30	94·24	94·64	95 03	95·42	95·81	96·21	96·60	96·99	30
31	97·4	97·8	98·2	98·6	99·0	99·4	99·7	100·1	31
32	100·5	100·9	101·3	101·7	102·1	102·5	102·9	103 3	32
33	103·7	104·1	104 5	104 9	105·2	105·6	106·0	106·4	33
34	106·8	107·2	107·6	108·0	108·4	108·8	109·2	109·6	34
35	110·0	110·3	110·7	111·1	111·5	111·9	112·3	112·7	35
Dia. in ft.	0in.	1½in.	3in.	4½in.	6in.	7½in.	9in.	10½in.	Dia. in ft.

Circumferences of **Circles** in feet and inches.

TABLE **21.**

Boiling point of liquids. **Melting point** of metals.

Effects of heat on various substances.

	Fahr.
Water is the best absorbent of heat (except mercury) and boils at	212°
Mercury (under atmospheric pressure of 14·7 lbs. pressure) boils at	676°
Steel becomes faint yellow colour at	430°
„ „ brown „ „	490°
„ „ purple „ „	530°
„ „ dark blue „	600°
Iron (lowest luminosity in the dark) at	635°
„ (red hot in the dark) „	800°
„ („ „ in daylight) „	1,272°
Heat of a common fire is	790°
Sulphur melts at	239°
Tin „ „	442°
Lead „ „	612°
Zinc „ „	773°
Copper „ „	1,996°
Silver „ „	1,832°
Gold „ „	2,282°
Platinum „ „	3,080°
Cast iron melts (minimum) at	1,920°
„ „ „ (maximum) „	2,786°
Wrought iron melts (minimum) at	2,730°
„ „ „ (maximum) „	3,945°

TABLE 22.

Temperature and *apparent* **pressure** of Steam per square inch, *i.e.*, as shown by Steam Gauge, exclusive of the atmospheric pressure.

Fah.	lbs. Pressure.	Fah.	lbs. Pressure.	Fah.	lbs. Pressure.
212°	0	257°	19	358°	135
216°	1	259°	20	363°	145
219°	2	267°	25	368°	155
222°	3	274°	30	373°	165
225°	4	281°	35	377°	175
228°	5	287°	40	381°	185
230°	6	292°	45	401°	235
233°	7	298°	50	417°	285
235°	8	303°	55	430°	335
237°	9	307°	60	445°	385
240°	10	312°	65	456°	435
242°	11	316°	70	467°	485
244°	12	320°	75	487°	585
246°	13	324°	80	504°	685
248°	14	328°	85	519°	785
250°	15	334°	95	533°	885
252°	16	341°	105	546°	985
254°	17	347°	115		
255°	18	353°	125		

TABLE 23.

Fractions of **inches**, feet, and yards, and their equivalent in Decimals.

Lineal Measure.

Fraction of an inch.		Diameter an inch.	Inches.		Feet.		Yards.
$\frac{1}{32}$	=	·03125	$\frac{1}{4}$	=	·02083	=	·0069
$\frac{1}{16}$	=	·0625	$\frac{3}{8}$	=	·03125	=	·0104
$\frac{1}{8}$	=	·125	$\frac{1}{2}$	=	·04166	=	·0138
$\frac{3}{16}$	=	·1875	$\frac{5}{8}$	=	·05208	=	·0173
$\frac{1}{4}$	=	·25	$\frac{3}{4}$	=	·0625	=	·0208
$\frac{5}{16}$	=	·3125	$\frac{7}{8}$	=	·0729	=	·0243
$\frac{3}{8}$	=	·375	1	=	·0833	=	·0278
$\frac{7}{16}$	=	·4375	2	=	·1667	=	·0556
$\frac{1}{2}$	=	·5	3	=	·25	=	·0833
$\frac{9}{16}$	=	·5625	4	=	·3333	=	·1111
$\frac{5}{8}$	=	·625	5	=	·4167	=	·1389
$\frac{11}{16}$	=	·6875	6	=	·5	=	·1667
$\frac{3}{4}$	=	·75	7	=	·5833	=	·1944
$\frac{13}{16}$	=	·8125	8	=	·6667	=	·2222
$\frac{7}{8}$	=	·875	9	=	·75	=	·25
$\frac{15}{16}$	=	·9375	10	=	·833	=	·2778
			11	=	·916	=	·3056
			12	=	1·	=	·3333

TABLE 24.

Relative Weights of Metals.

	Wr' ght Iron.	Cast Iron.	Steel.	Brass.	Copper.	Lead.	Zinc.
Iron (Wrought) being 1	1·	·93	1·01	1·09	1·15	1·48	·92
Iron (Cast) ... ,, 1	1·07	1·	1·08	1·17	1·23	1·56	·99
Steel .. ... ,, 1	·99	·92	1·	1·08	1·13	1·46	·91
Brass ... ... ,, 1	·92	·85	·93	1·	1·05	1·35	·84
Copper ... ,, 1	·87	·81	·88	·94	1·	1·29	·80
Lead ... ... ,, 1	·68	·63	·69	·74	·78	1·	·62
Zinc ... ... ,, 1	1·09	1·01	1·10	1·18	1·25	1·61	1·

EXAMPLES OF THE USE OF TABLE 24.

1. If a copper forging weighs 70 lbs., what would be its weight in steel?

   70 × ·88 = 61·6 lbs.

2. If an iron casting weighs 112 lbs., what would be its weight in brass?

   112 × 1·17 = 131·04 lbs.

TABLE 25.

Weight of **Cast**-Iron **Pipes** per Lineal Foot.

Dia. of Bore.	Thickness of Metal.								
	¼in.	⅜in.	½in.	¾in.	1in.	1¼in.	1½in.	1¾in.	2
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	l
1	3·05	5·85	7·35	12·9	19·7	—	—	—	-
1½	4·28	6·9	10·6	16·6	24·4	—	--	—	-
2	5·5	8·7	12·2	20·2	29·25	39·5	—	—	-
2½	6·73	10·5	14·6	23·5	34·2	46·6	—	—	-
3	7·95	12·5	17·1	27·4	39·0	51·75	—	—	—
3½	9·15	14·25	19·5	31·0	43·9	58·0	—	—	—
4	10·4	16·0	22·0	34·7	48·8	64·75	80·5	—	—
4½	11·62	17 9	24·4	38·3	53 7	70·5	87·5	—	--
5	12·8	20·	26·8	42·0	58·6	76 3	95·4	—	—
5½	..	21·8	29·3	45·6	63·5	82·5	103·0	—	—
6	..	23·6	31·75	49·5	68·5	88·2	110·0	133·	156
6½	..	25·4	34·2	52·8	73·2	94·6	117·0	141·	166
7	..	27·	36·5	56·6	78·0	101·0	125·0	150·	176
7½	..	28·8	39·	60·3	83·0	107·0	132·0	158·	186
8	..	31·0	41·4	64·0	87 5	112·8	139·	166·	196
8½	.	..	43·8	67·5	92·4	119·	146·	175·	206
9	..	..	46·3	71·2	97·5	125·	154·	183·	216·
9½	..	..	48·6	74·8	102·5	131·	161·	192·	226·
10	..	..	51·1	78·5	107·	137·	169·	200·	236·
10½	..	..	53·6	82 5	112·4	143·	176·	209·	246·
11	..	..	56·2	86·0	117·0	149·	183·	217·	255·
11½	..	..	58·5	89·5	122·	155·	191·	227·	265·
12	..	..	61·0	93·5	127·	161·	198·	235·	275·
12½	..	..	63·5	97·3	132·	167·	205·	243·	285·
13	..	..	66·0	101 0	137·	173·5	212·	252·	294·
13½	...	..	68·4	104 8	141·5	179·	219·	260·	304·
14	..	..	71 0	108·2	146·	185·	227·	269·	314·
14½	..	..	73·4	112·3	151·	192·	234·	277·	324·
15	..	..	75·8	115·7	156·	198·	242·	286·	334·
15½	..	..	78·1	119·0	161·	204·	250·	295·	344·
16	..	..	80·7	123·	166·	211·	257·	303·	353·
16½	.	..	83·1	126·5	170·5	217·	264·	312·	363·
17	..	..	85·5	130·	175·5	223·	271·	322·	373·
17½	..	..	87·8	133·5	180 5	229·	278·	330·	383·
18	..	..	90·5	137·	185·	235·	285·	338·	393·
18½	..	..	93 0	140·5	190·	241·	293·	347·	402·
19	..	..	95·5	144·8	195·	247·	300·	354·	412·
19½	..	..	97·8	148·5	200·	253·	307·	363·	422·
20	..	..	100·0	152·	205·	259·	315·	372·	432·

The above weights are for pipes with plain ends.
For weight of Socket and Spigot add one foot.
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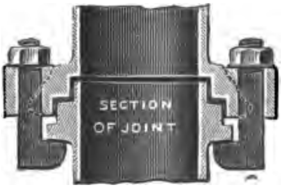

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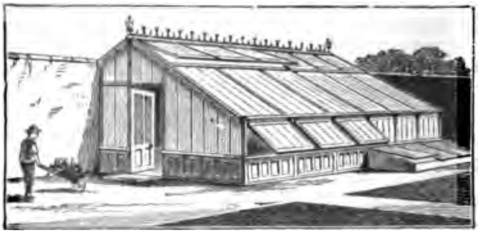

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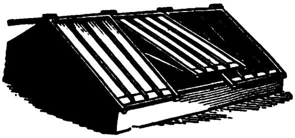

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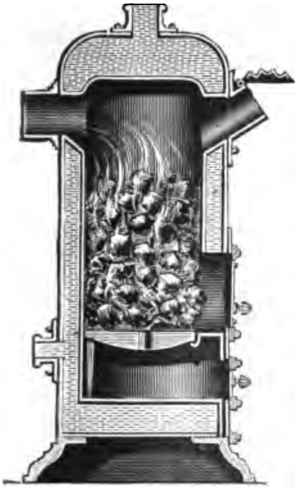

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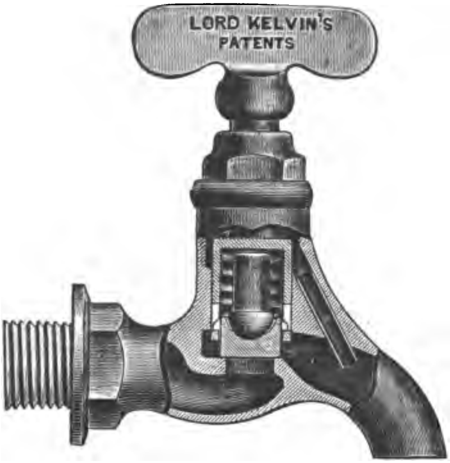

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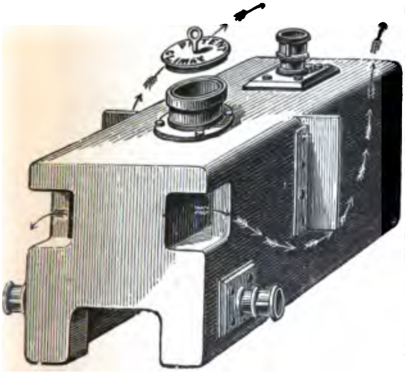

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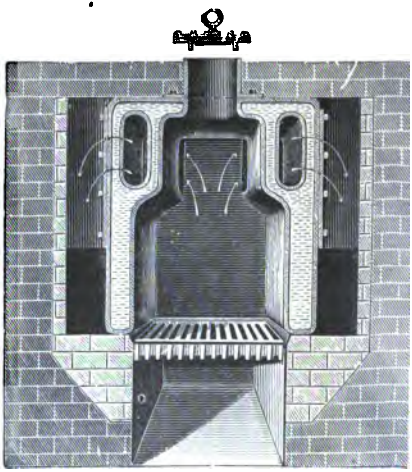

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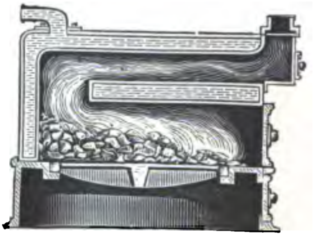

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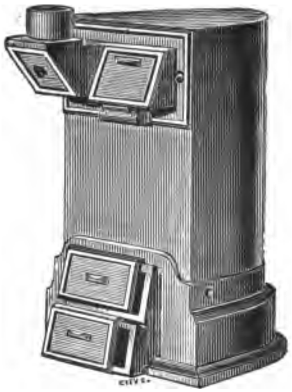

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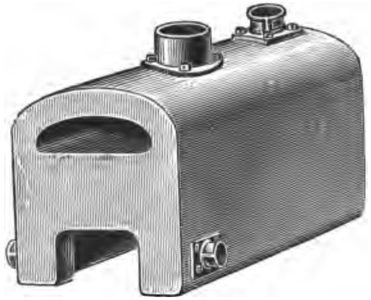

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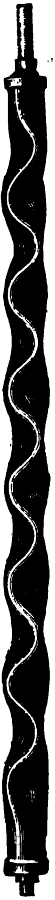

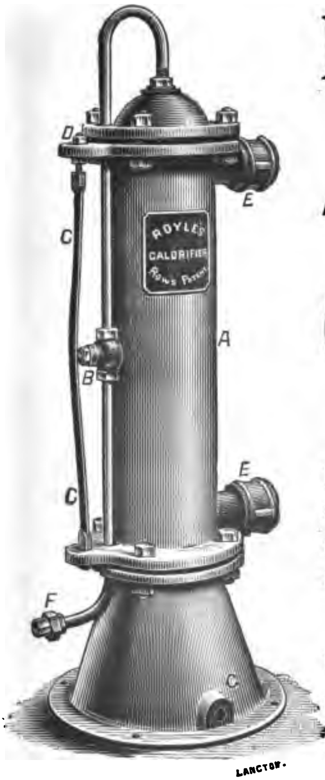

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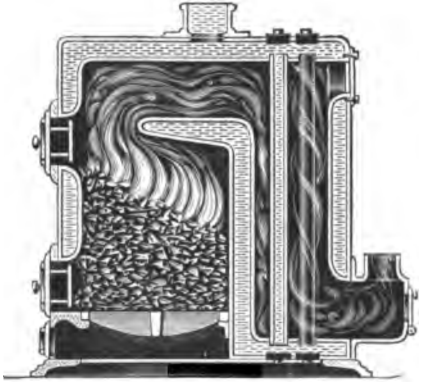

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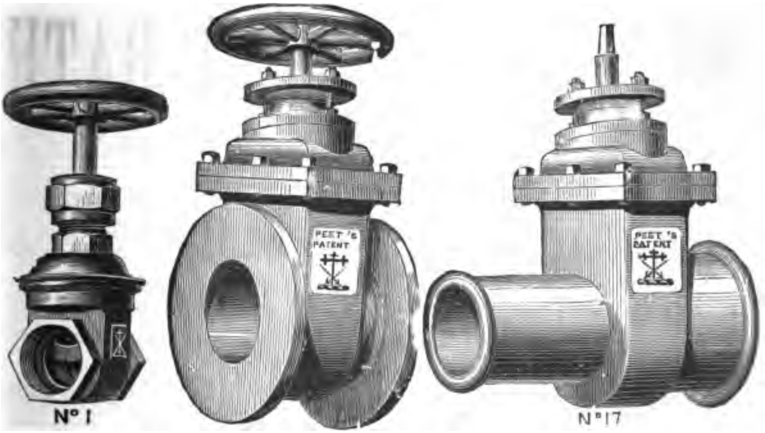

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